Charging Station for Electric Bikes Powered by Renewable Energy

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Title page

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Declaration of authorship I hereby declare that my project group and I prepared this project report and that all sources of information have been duly acknowledged

Preface

This project report is part of the final hand-in for the ENG-FPRPM-S22 course at VIA University College in Horsens. The report focuses on solving the business problem of creating sustainable charging stations for electrical bikes. It is split up into two parts, the first focusing on the business aspects, and the second one focusing on the mechanical aspects of answering the business problem and all the sub-questions.

The following report is an assignment from the ENG-FPRPM-S22 project and will be assessed by our supervisors Lene Overgaard Sørensen and Per Ulrik Hansen.

Our group would like to thank the supervisors Mrs. Sørensen and Mr. Hansen for providing us with helpful feedback and advice and for answering all our questions. Additionally, we want to thank our lecturer Martin Møhl for managing the course by giving us helpful introductions to the project and requirements.

Furthermore, we would also like to thank all students who were willing to provide us with feedback and exchange knowledge with our team. This helped us to conduct further research and analysis which lead to other possible opportunities and methods. We would also like to thank all lectures that provided us with useful content in the weekly workshops.

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Summary

This report serves the purpose to answer the research problem of developing a charging station for electric bicycles powered by renewable energy allowing rental companies to create a safer and more sustainable way of commuting. The report was divided into a business and a mechanical part to provide a better overview of each area of operations. The business part focuses on the establishment of the company, SolHavn, the analysis of the market environment and customers, as well as the creation of a suitable marketing strategy, and the projection of the expected financial positioning of the company. Further on, the previously defined sub-questions were answered.

Based on the research done, it was concluded that SolHavn is operating in a rather new market, with no direct competitors. The company has the best chances to attract potential customers by addressing them directly, for example at industry-specific fairs or through individualized online marketing. While doing so, the company should set emphasis on its key success factors, which included sustainability and security. Looking at the financial part, one can see that SolHavn needs a high initial investment to buy the materials and attract customers, which can be reached through crowdfunding. The company is expected to make a positive profit in the first year and grow and develop over time.

On the other hand, according to the mechanical calculation, assumption and analysis realized, this paper demonstrated the correct and accurate method to dimension and design the solar charging station. The value of the energy consumption was estimated in for the off-grid station and it mainly focused for the worst-case scenario that would happen even though the probability is quite low in Barcelona. The report focused on charging 10 number of solar stations throughout the consideration of losses that would happen in the electrical cabling and other component like step down, charge controller and other related.

The design in CAD to demonstrate the suitable design was shown and it would been able to support the load of chosen solar panel and other natural loads. Besides, other simulation which involved another scenario like hybrid and on-grid was considered and analyzed. The comparison between these other scenarios helped in improving the solar station for further project.

Introduction

This report was written as part of the FPR Project course during the spring semester at VIA University College in Horsens. The report is based on supporting lectures that helped the students identify a project and provide guidance about how to analyze this project professionally. The course started with setting up groups and brainstorming about current problems that could be solved. Once the group decided on a project to work on during the semester, the next step was to create a project description to provide the supervisors with a first overview of the purpose of the project and additional background information. Besides this report, the group is also submitting a process report that reflects on the group´s work and collaboration with each other.

The group has created the following problem statement: “Develop a charging station for electric bicycles powered by renewable energy allowing rental companies to create a safer and more sustainable way of commuting.”

This statement reflects the urge of society to drastically change its methods of transportation to a more sustainable way, as the negative effects of climate change are affecting humankind more than ever. The group sees this project as a great opportunity to make a change and allow people to think outside the box and care more about the future of the planet.

The group decided to put certain topics into the delimitation due to limited resources, such as time and expertise. These delimitations include the technical intricacies of how solar panels and batteries work. Further on, the project group does not investigate the real estate process for the individual countries it is targeting, due to the fact, that the report mainly delves into the technical mechanic's aspect of the charging station and ensuing business. Also, due to the absence of software engineers in the group, a focus was not placed on the corresponding app or software design that takes part in the booking process.

List of abbreviations

Benelux	Belgium, Netherlands, Luxemburg
COGS	Costs of goods sold
CSF	Critical success factor
DACH	Germany, Austria, Switzerland
DoD	Depth of Discharge
EBITDA	Earnings before interests, tax, depreciation, and amortization
ECS	Electrical Charging Station
Electrical bikes	E-bikes
ESH	Equivalent Solar Hours
JIS	Just in Sequence
MPPT	Maximum Power Point Tracking
PSH	Peak Solar Hours
PV	Photovoltaic Cell

1. Business introduction

1.1 Problem

Due to the COVID-19 outbreak and the subsequent lockdowns the risk of contamination through public transport, people are showing an increased interest in buying their means of commute.

Apart from increasing consumer preference toward recreational and adventure activities, the adoption of electrical bike (E-bike) applications in several sectors, like logistics and e-bike rental services, is expected to drive the market during the forecast period. As cities worldwide emerge from lockdowns, the demand for e-bikes is picking up pace due to their convenience and cost of operations. With growing concerns about vehicle emission and traffic congestion, across the world, a few automakers, like General Motors, Audi, and BMW, have been planning to enter the growing e-bike market, in order to diversify their portfolios (LLP, n.d.).

Electric bikes are a flexible and trendy mode of transport. Consumers look to them as an ideal substitute for scooters, cars, buses, etc. The bikes help tackle traffic congestion, owing to the smaller size of e-bikes, attain higher speed with lesser effort, and health benefits attained with peddling. These factors lead to a rise in the popularity of electric bikes across the globe, but the lack of the proper infrastructure possess a problem.

1.2 Solution

Develop a charging station for electric bicycles powered by renewable energy, allowing rental companies to create a safer and more sustainable way of commuting. Through the utilization of solar panels to harvest the sun as a continuous source of energy, this entire market can be propped up by fully renewable energy. Factors such as the implementation of government regulations to encourage the use of electric bikes, consumer inclination toward the use of e-bikes as an eco-friendly and efficient solution for commute, increase in fuel costs, and rise in interest in cycling as a fitness and recreational activity are expected to drive the market growth. Furthermore, improvement in bicycling charging infrastructure and battery technology is expected to offer lucrative opportunities for the electric bike market growth.

1.3 Briefly define your customers

SolHavn's primary customers are e-bike rental companies that own a large fleet of bikes and are looking for an innovative and secure way to charge them. These established companies will have the necessary capital to purchase the charging stations and have fleets of bicycles across the globe allowing a partnership to flourish and ultimately facilitate the expansion.

E-Bicibox is of particular interest as a new subscription to the Bicibox service that offers a public fleet of 300 e-bikes in 45 stations around 11 municipalities. E-Bicibox offers season tickets which allow customers the daily use of bicycles, as the company's ambition is to encourage sustainable methods of transportation for all sorts of travel and every type of citizen. It is for this reason that E-Bicibox offers electrical bicycles which are able to make long and steep journeys. The pass gives people to opportunity to rent the electrical bicycles for a total of 24 hours and entitles them to a Bicibox parking space throughout their rental period.

The number of municipalities that have signed on to the service continues to grow. E-Bicibox has the intention to expand to twelve municipalities, with the bikes being able to be picked up in any of the offered municipalities and can be dropped off in any other at the end of their journey.

To expedite the switch to electric, Barcelona is one of the few European cities looking into a charging infrastructure for electric vehicles. The city is looking to test solutions such as smart planning tools in order to determine optimal locations for new stations, as well as develop a wireless charging station for e-cars and e-bikes that use renewable energy.

1.4 People

SolHavn constructs highly sophisticated e-bike charging stations that are powered via renewable energy sources in Barcelona, Spain. The business is structured as a partnership in which equity shares are split evenly under Alex Espino, Cristian Boschi, Meor Mohd Afifi Bin Meor Affendi, Laura Valeria Ladino, and Lucca Eva Pütz. Underneath is a team of ten highly skilled professionals well experienced in mechanical engineering and electronics. SolHavn was founded in Copenhagen, Denmark in 2020 due to the rise in demand for e-bikes caused by the COVID-19 pandemic. SolHavn is determined to bring renewable energy and battery technology to the forefront of society in order to facilitate a sustainable future. The company intends to create a charging infrastructure that is powered by sustainable energy around Europe by 2030.

1.5 Company purpose

The topic of renewable energy and sustainability is of utmost importance to SolHavn and remains to be the primary driving force for the company. Sustainability vastly improves the overall quality of life, serves to preserve ecosystems, and conserves natural resources for all future generations. Regardless of who an individual may be, where they are from, or what they do, each and every person has a moral obligation to this planet and those whom they share it with, be it people or other species, as well as those generations that are yet to come, in order to sustain the world.

The present-day choices have cataclysmic long-term impacts on the state of the world and how it will eventually unfold. Championing sustainability ensures that those present-day choices steer those unfolding into a positive manner that can bring about a safe and livable future across time. Depleting the Earth's resources will simultaneously deplete future generations. For example, in the case of overfishing in the oceans, the issue does not only lie in the face value of depleting the fish supply, but more so in the chain reactions, it may cause. When depleting a supply of resources, it inadvertently impacts another facet of the planet, in this cause the supply of every organism in the ocean-related to the fish in the food chain. Sustainable actions are a thorough step in making a long-lasting change in society. When SolHavn focuses on sustainability, the entire world reaps the reward and is able to live in healthier living conditions.

2 The company

2.1 Vision

The company envisions to transform the transportation industry towards a more sustainable and eco-friendly future. SolHavn sees itself as the number one partner for all bike-sharing companies across Europe within the next ten years.

2.2 Mission Statement

Our mission is to develop a charging station for electric bicycles powered by renewable energy allowing rental companies to create a safer and more sustainable way of commuting. Creating a charging infrastructure that is powered by sustainable energy around Europe by 2030.

2.3 Company Values

2.3.1 Healthy Lifestyle

Employees make an effort to lead a healthier lifestyle for themselves and their families. In today's society, people are increasingly anxious about high-stress levels, unhealthy diets, and inactive lifestyles. As a result, the company has pivoted toward providing more support, flexibility, and rewards towards creating a more robust and well-rounded lifestyle. A facet of sustainability is working on remaining healthy in order to live long and well enough to enjoy the fruits of our labor.

2.3.2 Learning

To be learning-oriented, SolHavn values learning new knowledge and being receptive to new ideas. The company must be able to dispense with outdated methods and theories to make way for relevant new models. Continuous learning allows employees to find ways to better combat the unexpected and converse through perspectives with ease.

2.3.3 Innovation

Learning also plays a fundamental role in the devotion toward innovation. It is only through constant adaptation and enhancements of the company's processes and technologies that allow product lines improve for an existing customer base. To obtain a vital player in the market, innovation must be pursued ferociously. At SolHavn, the mindset of innovation is infections reserved for a singular department or specialized group. It is sewn into the company's culture that seeks to occupy the mindset of every employee in order to bolster ideas that have never been thought of before.

2.3.4 Measurements

Employees track and measure the activities carried out, evaluate results, and determine what methods are most rewarding and which are antique. They think critically to continually improve their innovation strategies by using data and analysis, sharing findings with colleagues, and openly communicating about results.

2.3.5 Quality

Employees always strive to produce excellent work that pushes the company forward. They wholeheartedly embrace responsibilities bestowed upon them and enjoy the arduous process of solving problems to provide effective solutions and give value to customers. Upholding quality ensures customers will return as they become further acquainted with the company's undeterred commitment to excellence.

2.4 Goals

1. Secure funding to build charging stations
2. Solidify relationship with E-Bicibox
3. Getting and staying profitable
4. Sustainable growth
5. Staying ahead of the competition
6. Create a network of sustainable charging stations around Europe.

3 Risk Analysis

LIKELIHOOD ↓ / SEVERITY →	1	2	3
1	LOW – 1 – Difficulties in the analysis of competitors	LOW – 2 – Unclear trends for the market potential	MEDIUM – 3 – Target group does not recognize value
2	LOW – 2 – Not enough renewable resources	MEDIUM – 4 – Unable to design stable and safe building	HIGH – 6 – Financial bottlenecks due to miscalculated figures
3	MEDIUM – 3 – Covid-19 carrying a negative impact on commuting	HIGH – 6 – Regulatory requirements	HIGH – 9 – Not enough sun the entire year

Figure 1 Risk analysis

Doing a risk analysis can help a company identify potential risks and find solutions for them before they occur. The figure above provides information about potential risks that might appear, in relation to their severity and likelihood of appearance for SolHavn. Three low-level risks might occur, including the difficulties to identify the competitors of SolHavn, not being able to identify the market potentials and trends, and not finding the fitting renewable resource to implement in the stations. As the likelihood and severance of these risks are at a rather low level, they should be acknowledged but not all priorities should be set on them.

Next up, there are three medium risks that SolHavn must take into consideration, including the threat that potential customers do not value the sustainable charging stations and are not interested in the new concept. Another medium risk is that SolHavn is unable to design the building safely and stably to store the bikes and produce renewable energy.

The last medium level risk is, that the ongoing COVID-19 pandemic is taking unforeseen changes and has a negative impact on the way people commute. These medium risks should be overviewed closely and backup plans to solve them should be created.
At last, the company is facing three high risks that are very likely to occur and would have a high impact on the company. One of these risks is the financial challenges that the company has to overcome to be successful. As there is a high initial capital needed to buy all the needed materials and attract potential customers, the company has a high risk to fail at this point.
Another major risk that SolHavn needs to avoid is potential regulations and laws that might stop the company from operating. The company needs to make sure that it knows all rules and regulations, before entering a new market. The last major risk is that there is not enough solar power available to fill up the batteries of the bikes. Without renewable energy, the company loses its competitive advantage over other competitors. It is highly important that SolHavn focuses on these high risks and sets priorities for avoiding them.

4 Product and concept

4.1 Core product

The core product of SolHavn is its sustainable and solar-powered charging stations for electric bikes. These charging stations offer space for up to ten bikes at the same time. The stations are equipped with eight solar panels on the roof, that capture the sun and turn it into energy to charge the e-bikes. The charging stations are built from robust materials that offer efficient protection for expensive e-bikes. The bikes will be protected from vandalism and robbery, but also environmental influences such as rain, hail, and snow. By being protected from three sides, the bikes can be used for a longer period and the rental companies can save money.

The end consumer can open the individual docking stations with a corresponding app and easily take the bike out and bring it back after use. To charge the bike, it simply has to be put into the docking station and will be charged through a cable. In this way, a quick and easy user experience can be ensured, and the customer is kept satisfied.

Inside the charging stations is a battery, that is connected to the solar panels and saves additional energy. This energy can then be used during the night or on less sunny days when the sun is not sufficient enough to charge all bikes. Further on, the possibility of selling the additional energy, that is saved in the battery, exists to raise additional profit, and increase the use of renewable energy.

4.2 Customer Values

The features of the charging station include the solar panels and sustainability aspect that drive the power necessary to charge the e-bikes. Within eight hours the bikes should be fully charged if starting from complete depletion therefore, overnight charging will ensure the bikes are ready until morning. The battery design also allows for the excess energy of the solar radiation to be stored and implemented at later times when sun levels may not be high enough to provide the necessary energy. The charging stations are placed in a location that will be most prime for demand. They will be strategically placed near highly used areas such as bus stations, train stations, community centers, sports facilities, bus stops, and other big economic areas. Traditional grid connections can be costly, especially in high traffic areas, but SolHavn's charging stations are able to remedy those issues. The average life cycle of a bike in a public sharing system is no more than eight to ten years and batteries last roughly five years (Bicibox, 2022). The benefit of the charging station is that it provides adequate protection and aims to prolong the lifespan of the bikes in order for customers to greater reap their investment. The value in all of this is the fact that it drives transportation towards sustainability and creates a paradigm shift in the masses. There are many sustainability benefits, both short-term and long-term. People cannot maintain the Earth's ecosystems or continue to function as we currently do if more sustainable choices are not made. If harmful processes are maintained with no change, humankind will likely run out of fossil fuels, huge numbers of animal species will become extinct, and the atmosphere will be irreparably damaged. Clean air and nontoxic atmospheric conditions, growth of resources that can be relied upon, and water quality and cleanliness, are all benefits of sustainability.

4.3 Production

The production of the charging station is split into individual stages. The first step requires the frame of the structure to be established naturally before all subsequent phases. Four iron ridge XR-10 rails run across the horizontal distance of the structure in order to uphold what will be the roof. Each charging station is held up by four beams and has eight aluminum rectangular hollow tube sections that uphold the ceiling. The ceiling is made of corrugated plates that are lightweight, break-resistant, and UV/Weather resistant while possessing sufficient strength to carry the solar panels. On top of the roof rests the 8 Luxen Solar 300W mono panels for their high efficiency of power output and performance. The walls are then installed at the end in the form of panels that are made up of sheet surge plates that are durable enough to protect the stewarded bikes.

In the interior of the charging station stands the screen at the very center with five e-bike porting stations on each side. The screen allows the customer to lock and unlock the e-bikes from the charging point with a connection interface of the app. Towards the right side of the charging station maintains a space dedicated to the three battery packs. Manufacturers recommend a busbar for installations of two battery packs or greater. The use of battery packs also requires further planning and adding on instruments such as power trackers, step-down DC converters, and protection cabinets that ensure the charging station works in a safe and efficient manner. There will also be a total of 22 white, green, and red lights that will be inside the charging station to ensure sufficient lighting throughout all times of the day.

The scheduled operation budget calls for three hours to perform the necessary sales calls and submit the orders for all the necessary materials. Assembly time requires 250 hours to put together the fragmented parts of the structure and fully construct it. Research and development also cannot be forgotten and must be considered to ensure the company does not fall behind and continues to remain competitive. Factory acceptance tests are necessary to verify that the system and its components are working to the agreed specifications and not facing any system malfunctions. Site acceptance tests also take place after the structure has been fully installed and configured. Considering having a product that is of high quality, it becomes necessary to also have marketing efforts and host sales meetings to reach out to prospective buyers. Once the sale has been made, it is also expected that 20 hours to be necessary for after-sales services over an extended period.

5 Macro environment analysis (PESTEL)

Using the Pestel Analysis one is going to analyze the macro environment of the company in Barcelona. In detail, one will have a look at the current and future standings in Barcelona as well as the conditions for successful business development in the given environment. Before the company's macroenvironment can be evaluated, two assumptions must first be made. First and foremost, one is assuming, that at, the beginning of its success story, the company will develop itself mainly in Barcelona as well as it is going to focus exclusively on the weather and e-bike trends.

5.1 Political & Legal Factors

Governments from across the globe are taking strides to reduce carbon emissions by encouraging the use of electric vehicles and electrical bikes. In addition, they aim to raise awareness of the perilous effects of relying primarily on fossil fuels. Urban planners are even constructing bicycle-friendly streets to bolster commuter levels of using bicycles as a primary means of transportation. E-bikes have proven themselves to be reliable and efficient ways of reducing nations' carbon footprints. Also, to encourage the use of electrical bikes, governments have implemented plans to sponsor the move towards electric mobility through tax credits and incentives. Also, during the pandemic and government restrictions placed on public transport, people were much more adept at adopting e-bikes as a mode of transportation from day today. This effect was largely exacerbated by the addition of social distance measures.

In addition, governments of various countries focus on the development of infrastructure facilities such as guarded bicycle parking facilities, construction of more bicycle (express) routes, and the establishment of battery charging stations in many countries by the governments significantly boost the adoption of electric bikes by users, thereby propelling the growth of the E-bikes market.

5.2 Economic

Now more than ever, the cost of fuel at an international level is reaching an all-time high. Pollution levels have also increased, as well as traffic congestion with higher birth rates as quality-of-life increases. The higher cost of fuel and maintenance, however, accrues the likelihood of preference towards electrical bikes as the main method of commuting and causes significant staggering growth in the market.

Due to the structure of the European electricity market, the price of electricity is largely interdependent on the price of natural gas thereby doubling in price over the last year and rising by 20% since February 2022 (BOE, 2022).
Spain has the luxury of possessing a stable economy and facing the issue from higher ground, having its highest level of employment since 2008 and in full swing of reform and investment program of the Recovery, Transformation and Resilience Plan, having one of its main pillars in the energy transition. On the other hand, inflation rates have also increased by around 5% starting from roughly zero at the beginning. This change came because of the energy prices increasing and the accompanying price of goods or services that so heavily rely on those energy sources throughout their production process. The rise in energy price has a reverberating effect on all the sectors dependent on it such as transportation, agriculture, livestock, etc, in order to operate and have very little wiggle room to deviate in price. It also has an effect on individuals as both electricity and inflation trickle down in the economy and reduces the amount of disposable income of everyone, especially those already financially vulnerable.

5.3 Environmental

Environmental factors play a potent role in the renewable charging station. Due to the nature of the station harvesting the sun as a means for power, the weather conditions in Barcelona play a fundamental role in the product's performance. Global warming and changing weather patterns can have a grandeur effect when it comes to expanding infrastructure efforts throughout the world. On the same side of that coin, the rising levels of carbon emissions cause these charging stations to be even more important to the world's future than ever. Natural resources will eventually be depleted if continued on this path and must be replaced with alternative sources of energy.

5.4 Social

Regarding career attitudes and health consciousness, the Spanish society shares a common mindset of health and efficiency. Utilizing e-bikes as a primary means of transportation is not only better for the environment and more convenient at times but also a much healthier alternative than cars, trains, buses, etc for the individuals. E-bikes allow couples, families, and groups of people to travel collectively regardless of their fitness and experience levels across various routes and distances. Cycling is an effective way of staying fit, saving on transportation costs, and also being able to enjoy the world outside and taking a break from the busyness of daily life.

Aside from the accumulating levels of customer preference toward e-bikes as a recreational and primary activity, e-bikes are being used in several other sections such as logistics and e-bike rental services. Several cities in Spain and all over Europe have urban planners that dedicate lanes in cities and suburban areas to better assimilate cycling into people's lifestyles. Even delivery and emergency-related services have begun to utilize e-bikes to deliver essential packages. In densely populated cities, it is the only way to avoid traffic congestion and arrive at locations in the timeliest manner. The e-bikes have a high price tag especially when they are unique and signed to fulfill a purpose such as the medical field and need additional security to ensure their protection.

As cities worldwide emerge from lockdowns, the demand for e-bikes is picking up pace due to their convenience and cost of operations. As cities around the world emerge from lockdowns, the demand for e-bikes is picking up the pace of their convenience and cost of operations. Regions such as Europe are witnessing a shift in consumer motive for buying an e-bike from leisure to daily use.

5.5 Technological Factors

The biggest challenge facing desirers today is the weight of bikes which requires innovative methods to alleviate. The hefty weight of both the batteries and motors makes it more difficult for riders to maneuver, demanding much more effort in order to pedal or navigate. Initial e-bike models were bulkier, but newer iterations continue to become sleeker and more agile as engineers create lighter frames and mechanisms. Lightweight continues to play a vital role in the expansion of the e-bike market as they not only become more appealing but also improve battery performance and energy to power output to deliver optimal pedal assistance.

As the e-bike market around the world progressively grows over time, analysts are able to collect and analyze more data to better allows designers and engineers to better understand the key features that are mostly being used. Studies conducted on the average logged milage of bikes in unison with harvested data concluded e-bikes call for less battery capacity.

Furthermore, the technological advances in e-bikes cover various areas such as projection analytics, product development, wireless connectivity, urban planning tools, and 3D-printed parts. Steady technological breakthroughs enhance the safety, speed, and convenience of e-bikes while also being easier to track and measure. The e-bike industry will continue to thrive thus requiring the necessary charging infrastructure to power the bikes.

6 Microenvironment analysis (Porter´s five forces)

As there is no existing market with competitors that focuses on charging stations for electrical bikes, the group has decided to do this analysis for the customer market of bike rental companies.

6.1 Bargaining power of buyers

When looking at a new industry, customers are an important factor, as they are the ones buying the product or service and decide which company will be successful and which will not. Looking at the e-bike rental industry, the bargaining power of the buyers is very high, as they have the option to choose between various companies and transportation options. Though classic public transportation such as busses and trains are still the most popular method of transportation, shared and rental options such as e-scooters or bikes are rising in attractiveness.

One of the most important decision-making factors when it comes to choosing a transportation method is the cost of the service. Especially for short-distance transportation, consumers are mostly focused on the lowest price available and are willing to give up comfort for that. Besides the price of the transportation, the duration and availability play important parts. Based on these factors, potential customers often decide quickly which type of transportation they want to choose.

6.2 Bargaining power of suppliers

Another important factor that needs to be considered when entering a new industry is the suppliers operating in this industry and the power they have when it comes to negotiating. Looking at this specific industry, it can be said, that the suppliers have a rather low to medium ranged power.

This is based on the fact, that there is limited knowledge needed to produce electric bikes, and the electric bike production market is supposed to grow by over 12% in the next five years to reach a value of almost 55 billion USD (Mordor intelligence, 2021). Due to the limited knowledge needed and the rapidly growing market, more and more suppliers are entering the market, which allows the bike-sharing companies to have more options to choose from and take the best option for them.

6.3 The threat of new entrants

Looking at different threats that come with operating in a certain industry, the threat of new entrants can certainly not be ignored. In this particular industry, the threat of new entrants is very high due to several reasons. At first, the bike rental industry is a fast-growing market, with an expected increase of over six percent until 2026 (Wood, 2021). Especially the COVID-19 pandemic has increased the popularity of shared transportation and the bike-sharing industry (Wood, 2021). Due to the anticipated expansion of the market and its rising popularity, more and more companies are interested in the segment and willing to invest.

Another aspect that makes the threat of new entrance high, is the medium amount of investment needed to enter the market. The needed bikes can be produced cheaply due to a high economy of scale, the complementary app can be developed easily and due to limited maintenance and staff expenses, the profit margin can be increased. In combination with the medium amount of recourses and investment needed, there is also only limited knowledge needed to enter the market. One does not need any specific knowledge or background information about bikes and the concept of bike-sharing is commonly spread. Of course, there is a certain understanding about running a business and software development needed, but no in-depth specialization for this market. Due to these three aspects, the threat of new entrants in the bike-sharing industry is at a high level.

6.4 Threat of substitutes

In addition to the threat of new entrants, one also needs to be aware of potential substitutes, before entering the market. In this particular case, the threat of substitutes is extremely high, as there are many transportation alternatives available to the consumer. Looking at the shared transportation segment, one can see a rise in the popularity of electric scooters (e-scooters) over the last few years. In 2022 e-scooters are expected to bring a revenue of over 1,75 billion USD worldwide and are expected to grow to over 31 billion USD in 2028 (Fortune business insights, 2022). With this massive increase in revenue, e-scooters are a major competitor in the bike-sharing market.

Besides e-scooters, classic transportation methods such as cars, busses, trains, and walking are creating a high threat, especially on short- to medium-distance routes. In addition to multiple alternatives available, low customer loyalty also increases the threat of substitutes. A majority of the consumers do not have any company preference when looking for a transportation method, but rather focus on availability, comfort, and price. Therefore, it is important to create a business strategy that creates either a cost or differentiation advantage to stand out from the competitors.

6.5 Competition in the industry

The last part of Porter´s five forces analysis is the overall competition in the industry, which is based on the previously identified centers of power and threats within the industry. Overall, it can be said, that the competition within the bike-sharing market is high, as it is a fast-growing industry that attracts new companies to enter the market and create more competition. Not only is a competition created within the bike-sharing industry, but also in the overall transportation industry, as there is a big variety of substitutes available and potential customers are willing to switch from one transportation method or company to another, based on the availability, comfort, or price.

Further on, the competition is at a high level, as companies are constantly expanding their portfolio and creating new features and ways of transportation. In this way, companies can attract new customers and gain more market share in comparison to their competitors. Consequently, it is of major importance to constantly grow and develop the own company, add new features, and create a better experience for the customers to keep up with the competitors and create a sustainable competitive advantage.

7 SWOT

7.1 Strengths

To successfully operate in a market and create a sustainable competitive advantage, a company needs to know its strengths and weakness, as also potential opportunities, and threats. By clearly identifying its strengths, a company can highlight those even more and create a bigger competitive advantage. One of the biggest strengths that the company has is its sustainable business model. By combining the two uprising trends of bike renting and emission-free eco-friendly energy, the company is operating in a wide and popular field of business with promising looks into the future. Alone in Denmark, over 80 percent of the population has at least a moderate interest in sustainability and the effects of global warming (Videncentret Bolius, 2019). Of those Danes concerned about the environment, 52 percent are willing to change their energy supply to more sustainable sources and 39 percent are thinking about changing their transportation behavior to methods with less carbon dioxide emission (Videncentret Bolius, 2019).

Looking at these numbers, one can identify a clear trend toward more sustainability and more and more companies are jumping on that trend. Companies operating in the electrical bike-sharing industry are constantly looking for new sustainable innovations and alternatives to make their service even more appealing and create a competitive advantage. At this point, one can identify another strength of SolHavn, as it is one of the first organizations that offers independent and sustainable charging stations. It can help rental companies to create a greater competitive advantage and attract new customer groups.

Another major strength of SolHavn´s product is the security that comes with it. By building a surrounding and robust shelter to store the costly e-bikes in and installing security cameras, the chances for robbery or vandalism are being minimized. The charging stations do also offer protection from environmental influences such as rain, hail, and snow that might cause rust or other damage on the bikes and therefore expand the lifespan of the e-bikes.

7.2 Weaknesses

While it is important to highlight the strengths of a company, one cannot ignore the weaknesses that a company might have. By identifying their weaknesses, the company can find solutions to prevent those and turn them into strengths. At the same time, by ignoring potential difficulties, one creates an opportunity for the competitors to focus on that and therefore create a competitive advantage. Looking at the company, one can identify several weaknesses that the company needs to be aware of and find ways to eliminate or reduce them.

The first weakness that the company is facing, is the dependency of the charging station on the sun. To be fully independent and charge the bikes with renewable energy, a lot of sun is required. With a lack of solar power, for example, during the winter or in more northern countries, the business model does not work as efficiently as it should and therefore will not attract as many potential customers. To reduce this weakness to a minimum, SolHavn is implementing a battery that will be charged with excessive energy, produced on days with a high solar presence. This battery can be used on less sunny days. Additionally, the charging station will be connected to the energy grid of the city to provide a backup solution, in case there is no sun available, and the battery is empty. The use of the grid will be the last possible option and only be used in rare situations.

Another weakness that the company is facing, is that the initial costs for building a sustainable and secure charging station are substantially greater compared to common charging stations, powered by a normal electricity grid. The higher initial cost of the charging station is increasing the risk of less interested customers and might discourage them to have a more detailed look into the product and invest.

To avoid this weakness, it is of high importance to highlight that the initial cost might be higher, but that the solar-powered charging stations are less costly in the long-term view. This is due to the fact, that the charging stations are mainly independent of electricity prices made by the city or other common providers. Therefore, unforeseen events around the world have less influence and the costs are more stable over time. Additionally, governments around the world are focusing on renewable energy and support companies that operate with those in forms of funding or other benefits (Frankfurt School-UNEP, 2020).

In addition to that, the organization needs to be aware that the business model of a charging station powered by solar energy can be easily copied by other players and increase the competition in the market. Even with a patent of the specific design of SolHavn, opponents are still able to copy the overall concept and create a similar version with the same major features. To minimize this weakness, the company needs to create a broad customer range quickly and satisfy all their needs and demands. By building up a strong customer base early enough, the organization can create a sustainable competitive advantage and grow to a major player in the industry.

Overall, there are various weaknesses that the company needs to be aware of and take into consideration. It is important to not ignore these, but rather focus on them and find efficient ways to avoid them. By doing so, SolHavn will be able to create a long last competitive advantage.

7.3 Opportunities

At the current moment, there are not many charging stations that are fully reliant on renewable energy. Several bike charging stations of course do exist; however, they are reliant on conventional means of energy such as electricity or other nonrenewable sources. This presents an opportunity for our company in order to get ahead of the curve and fill a need in the market by constructing a network of fully self-reliant charging stations. Not only does the option of creating new bike stations from scratch exist, but the business also has the possibility to focus on the modification of the bike charging station by using advanced and eco-friendly features. The rising electricity prices in Spain also grant to put renewable energy sources in a favorable position economically. The upfront cost of solar panels is undoubtedly more expensive than traditional electricity however, over a long period of time that upfront cost begins to recuperate itself until it is ultimately paid for.

Commuting via bike has become even more popular and accessible throughout the world. Largely due to the COVID-19 pandemic and all the restrictions placed on public transportation including social distancing guidelines and general fear of getting sick, a sharp spike in the adoption of e-bikes as a method of commuting was observed. E-bikes are a convenient and affordable alternative to public transportation providing tremendous opportunity for market growth and the need for a public charging station.

There are also certain upcoming trends in electric bikes. People of today are also bred with a more environmentally progressive mindset and are more inclined to adopt the social responsibility everyone carries when it comes to stewarding the planet. Consequently, there is a growing concern in regard to taking care of and sustaining the environment and its resources, if not for the present but then for our children's generations and those proceeding.

The necessity of travel is also returning to pre-pandemic levels as countries slowly begin to return to normal. However, commuting levels returning to ordinary levels subsequently follow the increase in transportation emission levels. As a result, governments and organizations around the world are implementing strict emission standards with the purpose of reducing carbon emissions. The use of fossil fuel reserves presses a tenacious challenge for governments and societies which e-bikes can alleviate, creating an increasing demand in the market.

7.4 Threats

On the other side, the company however is not without threats. Due to the current state of the COVID-19 pandemic and mandates beginning to pacify, the once existing fear of using close quarters public transportation is now being remedied. At the start of the pandemic, many people feared traveling with other strangers in tight places that did not allow for social distancing. This led to the rise in sales of e-bikes as a means to efficiently commute without the fear of putting one's health at risk. Now with some countries no longer even requiring the wearing of face masks on public transportation, people around the world are open again to returning to their old ways. This could pose a possible threat to the growth of the bike market and thereby hinder the need for more charging stations. Concerning the market, another possible turn that may be faced in the years to come is a potential new form of energy such as hydrogen, or other niche means. Without constant innovation to pull solar energy to the forefront of the market, it may become possible that other forms of energy to become an integral part of charging and must closely be monitored and dealt with.

8 Marketing

A marketing mix is an essential tool when it comes to creating the business and marketing strategy of a company. A well-defined marketing strategy can help a company to grow and expand quickly and reach more customers in a shorter time. The marketing mix focuses on the four areas of product, price, place, and promotion, which are all essential parts of a good marketing strategy.

Looking at the product itself, the company will focus its marketing on the advantages that come with the product. These include the sustainable aspect, the easy implementation into the existing bike fleet, and being a pioneer in an uprising and trending industry. By highlighting the Eco-friendliness of the product, the company ensures its customers a long-lasting advantage, not only for the end-user but also for the environment, which becomes more and more important to not only normal consumers but also influences governmental and business decisions. Additionally, the marketing strategy of Solhavn will focus on product differentiation from competitors. By highlighting this aspect, the company can convince potential customers to invest in this innovation and create a sustainable competitive advantage.

Besides marketing the product, itself, the company needs to be aware of how to market the price that comes with it and justify how it comes together. For Solhavn, high-quality and long-lasting materials are of high importance, which automatically leads to a higher price. To still be able to bring the product close to the customers, despite the higher price, it is important to present a clear justification for the elevated price. This justification includes all the features and benefits of the product, the well-chosen high-quality materials, and the unique and innovative design of the charging station itself. Additionally, it should be mentioned that this product has an economy of scale, meaning the more charging stations are being manufactured and sold to a customer, the cheaper each station gets.

Next up, determining the right place to market and sell one´s product is important to reach the wanted clients. As the sustainable charging stations are a high-priced product, it targets a specific customer group and is therefore only available to fitting businesses in the transportation industry. These customers are attracted to the best at industry-specific trade fairs, that focus on innovations and allow SolHavn to get in contact with potential customers. Additionally, the product will be available online on the company´s website.

At last, a good promotion strategy is important to sell the product to the customers and gain market share. For SolHavn´s product, a direct promotion that targets the individual customers directly is the best option. Direct promotion can be done in terms of e-mail marketing, sales presentations to different companies, and targeting individual demands of potential customers. As the solar-powered charging stations are a unique and innovative product, it is important to take enough time for each customer to explain all features and highlight the benefits.

In conclusion, a well-defined marketing mix is of high importance to promote and sell the product effectively and efficiently. In detail, this includes highlighting all benefits of the product to the customers, especially with a few on a more sustainable future. Additionally, a good justification for the elevated price is important to not frighten any customers, but rather show the value behind the price. The charging stations will be promoted at specialized trade fairs and on the company´s website and individual sales presentations and email marketing will be created for the potential customers.

9 Key Activities

9.1 Business development

Building relationships with partners whether it ranges from supply chain management partners or single individuals who may refer customers down the road. Proper business development is intrusive towards every department within a company such as sales, manufacturing, finances, human resources, etc.

9.2 Market Research

It is crucial to continue learning about ever-changing customer motivations, and issues, as well as new and existing competitors. The electric bike and scooter industry are still relatively new and hold a great possibility for potential market shifts. To stay on top, it is significant to know if the market is expected to move in an upward or downward trend over the coming years in order to strategically steer the company into a more competitive position.

9.3 Sales

Involves going and finding more e-bike companies possessing the interest in having their charging stations. The sales team must make sure to follow up with clients as much as possible, as well as performance calls if needed, in order to establish a meeting and further along the buyer-selling process.

9.4 Marketing

Creating interest around the brand and product whether it be through content creation, paid advertisement, or other distribution channels. Direct promotion is another method that can be done via e-mail marketing, sales meetings, and targeting companies that seem like the best fit. Due to the nature of the product as a unique and innovative design, it is paramount to fully be able to explain all the features and benefits that customer may receive when buying the product.

9.5 Product Development

This phase includes the production process of the charging station itself, software development of the app, and continued upkeeping services after the customer makes the purchase. Responsibilities falling under this activity require a wide range of subsections such as problem-solving, researching recent breakthroughs in technology as well as upkeeping knowledge on the latest production techniques.

10 Key Resources

10.1 Prime locations and permits

In order to reap the highest rewards, the charging stations must strategically be placed in locations that are known to have many customers frequent such as the city center, big economic areas, education or sports facilities, train and metro stations, bus stops, etc. There are restrictions related to the connection of the grid as some points could be more expensive than others. Generally, pedestrian areas are not most suitable for bike stations or charging stations and are better suited for roadways besides bike lanes. Building in public areas is also not made possible without permits.

10.2 Materials

The automatic lock should be made of a highly resistant material that can withstand harsh conditions or weather. In addition, the material chosen must have high durability without the need for repair and replacement of a part. Besides, the installation of surveillance cameras to monitor both the station and electric bike from potential theft and vandalism.

10.3 Solar Panels & Batteries

Solar panels are integral to the design of the charging station obviously for their ability to harvest the sun and power the system. Without the reliance on the existing power grid, the charging station over time will be cheaper and recoup the initial investment through saves on energy expenses. It is also vital to design a battery system that can meet the charging demand of electric bikes and is capable of operating at a longer life cycle.

Develop a control system that can regulate and ensure a stable voltage distribution with minimum energy loss. Moreover, develop a protection system that safely isolates the station battery from further damaging the bike battery in case of power overload.

10.4 Large e-bike fleet

SolHavn intends on creating a charging infrastructure that is powered by sustainable energy around Europe by 2030. In order to reach the goal, a large fleet of e-bikes is necessary to drive such expansion and create sufficient revenue to be able to move on to the next city, state, country, etc. The current trends demonstrate that the e-bike industry will only continue to get larger and may potentially provide opportunities for not just commercial use of the charging stations but may eventually be able to be used for private individuals as well.

10.5 Expertise

Engineers/Expert knowledge is fundamental to the development of the company and the direction in which SolHavn can pivot. SolHavn's research and development team is in charge of analyzing data and designing and retrofitting stations with the latest innovation to handle the change in any market shifts or potential hurdles that may come up in the future.

11 Action and development plan

A company should always have a plan for its future, which states how and when the company plans to grow and develop. These goals and milestones are of high importance, as the company on the one side has a goal that it is working towards and keeps everyone within the organization motivated and on track. In addition, well-defined goals show potential customers the ambition of the company and its determination towards the product and its success and growth. As a start-up company in a rather newly created market with limited competitors, it is harder to set these goals, as there are fewer players to compare them to and see if they are realistic.

SolHavn created milestones for the next ten years that mainly focus on the expansion of the core product over various countries within Europe. Until the third quarter of 2023, the company is planning to implement 20 charging stations for Bicing in Barcelona, which would allow the company to charge up to 200 electric bikes with renewable energy at the same time. After establishing and expanding the stations in Barcelona and increasing its popularity amongst the customer and the end-user, the company is determined to grow in other major cities within Spain after three years. Based on the popularity of rental bikes in Spain, the expansion will mainly focus on the cities of Madrid, Valencia, and Sevilla (Observatorio de la Movilidad Metropolitana, 2020).

Once the solar-powered charging stations have gained popularity in Spain, SolHavn plans on expanding its business to France and Italy within the next five years. This is due to the previously mentioned fact, that Italy and France, besides Spain, create the biggest rental bike market in Europe and have optimal weather conditions for the solar panels. Within those two countries, Solhavn will again focus on the most popular cities for rental bike companies to expand the customer base and gain popularity. It is important to build a stable and resistant network before expanding further.

As the business will grow constantly, it is important to use this opportunity and expand further. After successfully expanding to Italy and France, SolHavn estimates the DACH and Benelux countries next in about seven years. These countries include Germany, Austria, and Switzerland for the DACH region, and Belgium, Netherlands, and Luxemburg for the Benelux area. It is best to expand to these regions next, as they offer enormous rental bike markets and come with a lot of business potential. On the other hand, the weather conditions are not as optimal as in Spain, Italy, or France and therefore these countries were not a priority at the start of SolHavn.

Looking ten years into the future form now, SolHavn sees itself being present all over central and southern Europe and having a well-established powerful network of partners and customers. By gaining more popularity over time, it will be easier for the company to expand to new markets on the continent and grow from a small start-up to a major player in the sustainable transportation industry.

12 Finances

12.1 Sales volume per year

Quantify sales-volume year by year										
	Year_1	Year_2	Year_3	Year_4	Year_5	Year_6	Year_7	Year_8	Year_9	Year_10
Max. Potential	25	50	100	200	350	500	800	1.200	1.700	2.100
Opt. %	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Exp.%	70%	70%	70%	70%	70%	70%	70%	80%	80%	80%
Pes.%	50%	50,0%	50,0%	50,0%	50,0%	50,0%	60,0%	60,0%	60,0%	60,0%
Number of units sold	Year_1	Year_2	Year_3	Year_4	Year_5	Year_6	Year_7	Year_8	Year_9	Year_10
Opt.	25	50	100	200	350	500	800	1200	1700	2100
Exp.	18	35	70	140	245	350	560	960	1360	1680
Pes.	13	25	50	100	175	250	480	720	1020	1260

Figure 2 Sales Volume per year

The first year holds the largest hurdle when it comes to sales. The potential highest amount of charging stations that can be sold in the first year is 25, juxtaposed to the lowest amount being 13 charging stations. The most optimistic projection will naturally be that of 100% though highly unlikely, especially as a startup. The most pessimistic projection yields a percentage of 50%.

The number of units sold in the first year is expected to be 18 charging stations. Afterward, the expected production rate will nearly double to 35 charging stations being produced in the second year. That growth rate is projected to continue roughly for the following two years until year six which will reach a slight slowing down.

12.2 Bill of materials

Bill Of Materials BOM:				
Item_No	Description	#	Unit_Cost	Total_€
1	Solar Panels	8	€ 191,00	€ 1.528,00
2	IRONRIDGE XR-10 RAIL, 17 FOOT	2	€ 40,65	€ 81,30
3	Aluminium Rectangular Tube Hollow Section	8	€ 8,94	€ 71,52
4	Lights (white)	2	€ 4,71	€ 9,42
5	lights (green& red)	20	€ 2,33	€ 46,60
6	Screen	1	€ 244,22	€ 244,22
7	Battery	3	€ 4.290,00	€ 12.870,00
8	Power tracker	1	€ 730,00	€ 730,00
9	Busbar	1	€ 48,28	€ 48,28
10	Protection cabinet	1	€ 175,50	€ 175,50
11	Stepdown DCDC converter	2	€ 6,05	€ 12,10
12	Roof	16	€ 9,99	€ 159,84
13	Walls	6	€ 32,15	€ 192,90
	Total Material Cost			**€ 15.976,78**

Figure 3 Bill of Materials

The bill of materials provides an overview of the needed materials for the charging stations, including the quantity needed and the total costs. The majority of the costs come from the three batteries that are needed to store additional energy and save it for a less sunny day. Besides the batteries, solar panels make up a major part of the material costs.

12.3 Investment plan and budget and depreciation

Investment Plan and Budget:			
Depriation over years:		**Investment Primo**	Year: €
20		Solar Panels	€ 1.528,00
25		IRONRIDGE XR-10 RAIL	€ 81,30
25		Aluminium Rectangular Tube Hollow Section	€ 71,52
5		Lights (white)	€ 9,42
5		lights (green& red)	€ 46,60
5		Screen	€ 244,22
10		Battery	€ 12.870,00
10		Power tracker	€ 730,00
10		Busbar	€ 48,28
25		Protection cabinet	€ 175,50
10		Stepdown DCDC converter	€ 12,10
25		Roof	€ 159,84
25		Walls	€ 192,90
		Total Investment	16.170

Figure 4 Overview of materials and expected life span

Depreciation Budget:											
	1	2	3	4	5	6	7	8	9	10	
Solar Panels	76,4	76,4	76,4	76,4	76,4	76,4	76,4	76,4	76,4	76,4	
IRONRIDGE XR-10 RAIL	3,3	3,3	3,3	3,3	3,3	3,3	3,3	3,3	3,3	3,3	
Aluminium Rectangular Tube Hollow Section	2,9	2,9	2,9	2,9	2,9	2,9	2,9	2,9	2,9	2,9	
Lights (white)	1,9	1,9	1,9	1,9	1,9	1,9	1,9	1,9	1,9	1,9	
lights (green& red)	9,3	9,3	9,3	9,3	9,3	9,3	9,3	9,3	9,3	9,3	
Screen	48,8	48,8	48,8	48,8	48,8	48,0	48,0	48,0	48,0	48,0	
Battery	1287,0	1287,0	1287,0	1287,0	1287,0	1287,0	1287,0	1287,0	1287,0	1287,0	
Power tracker	73,0	73,0	73,0	73,0	73,0	73,0	73,0	73,0	73,0	73,0	
Busbar	4,8	4,8	4,8	4,8	4,8	4,8	4,8	4,8	4,8	4,8	
Protection cabinet	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	
Stepdown DCDC converter	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	
Roof	6,4	6,4	6,4	6,4	6,4	6,4	6,4	6,4	6,4	6,4	
Walls	7,7	7,7	7,7	7,7	7,7	7,7	7,7	7,7	7,7	7,7	
Total Depreciation	1529,7	1529,7	1529,7	1529,7	1529,7	1528,9	1528,9	1528,9	1528,9	1528,9	15293,1

Figure 5 Depreciation budget

The investment plan and depreciation budget show the estimated lifetime of each compartment of the charging stations and its depreciation over time. It is estimated that the materials have a straight-line depreciation and have an annual loss of value of 1.529€. As the depreciation after 10 years of usage will only be around 15.293€, the customer has more value out of the station for a longer period, as a rest value of 8.706€ exists.

12.4 Income statement

Scenario:										
2	Year_1	Year_2	Year_3	Year_4	Year_5	Year_6	Year_7	Year_8	Year_9	Year_10
Units sold	18	35	70	140	245	350	560	960	1360	1680
Income statement:										
Euro	Year_1	Year_2	Year_3	Year_4	Year_5	Year_6	Year_7	Year_8	Year_9	Year_10
Revenue	431.982,00 €	839.965,00 €	1.679.930,00 €	3.359.860,00 €	5.879.755,00 €	8.399.650,00 €	13.439.440,00 €	23.039.040,00 €	32.638.640,00 €	40.318.320,00 €
Materials	291.054,24 €	565.938,80 €	1.131.877,60 €	2.263.755,20 €	3.961.571,60 €	5.659.388,00 €	9.055.020,80 €	15.522.892,80 €	21.990.764,80 €	27.165.062,40 €
Labour	89.460,00 €	173.950,00 €	347.900,00 €	695.800,00 €	1.217.650,00 €	1.739.500,00 €	2.783.200,00 €	4.771.200,00 €	6.759.200,00 €	8.349.600,00 €
Variable Cost	380.514,24 €	739.888,80 €	1.479.777,60 €	2.959.555,20 €	5.179.221,60 €	7.398.888,00 €	11.838.220,80 €	20.294.092,80 €	28.749.964,80 €	35.514.662,40 €
Contribution Margin	**51.467,76 €**	**100.076,20 €**	**200.152,40 €**	**400.304,80 €**	**700.533,40 €**	**1.000.762,00 €**	**1.601.219,20 €**	**2.744.947,20 €**	**3.888.675,20 €**	**4.803.657,60 €**
Margin %	*11,9%*	*11,9%*	*11,9%*	*11,9%*	*11,9%*	*11,9%*	*11,9%*	*11,9%*	*11,9%*	*11,9%*
Marketing plan expenses	€ 4.050,00	€ 7.875,00	€ 15.750,00	€ 31.500,00	€ 55.125,00	€ 78.750,00	€ 126.000,00	€ 216.000,00	€ 306.000,00	€ 378.000,00
EBITDA	€ 47.417,76	€ 92.201,20	€ 184.402,40	€ 368.804,80	€ 645.408,40	€ 922.012,00	€ 1.475.219,20	€ 2.528.947,20	€ 3.582.675,20	€ 4.425.657,60
Depreciation	€ 1.529,73	€ 1.529,73	€ 1.529,73	€ 1.529,73	€ 1.529,73	€ 1.528,88	€ 1.528,88	€ 1.528,88	€ 1.528,88	€ 1.528,88
EBIT	€ 45.888,03	€ 90.671,47	€ 182.872,67	€ 367.275,07	€ 643.878,67	€ 920.483,12	€ 1.473.690,32	€ 2.527.418,32	€ 3.581.146,32	€ 4.424.128,72
Profit	**€ 35.792,66**	**€ 70.723,75**	**€ 142.640,68**	**€ 286.474,56**	**€ 502.225,36**	**€ 717.976,83**	**€ 1.149.478,45**	**€ 1.971.386,29**	**€ 2.793.294,13**	**€ 3.450.820,40**

Figure 6 Income statement

To provide an overview of what the first ten years of the company´s business could look like, an income statement was created. The show income statement is based on the expected sales, the income statements for the optimal and pessimistic sales can be found in the appendices A and B. The income statement shows the main areas of income and expenses and provides an overview of the expected profit at the end of each year. Though the company is creating great revenue through the selling of its products, a major part of it is being used to cover the labor and material costs of the charging stations.

Further on, one needs to subtract the marketing expenses from the contribution margin, leaving earnings before interest, taxes, depreciation, and amortization (EBITDA) of around 46.000€ for the first year. As SolHavn does not pay any shares, only the yearly depreciation is subtracted from the EBITDA. After paying taxes in Denmark of 22% (PWC, 2022), SolHavn is expected to make a profit of 35.792€ in the first year of business.

12.5 Cashflow statement

Cash Receipts											
Year	1	2	3	4	5	6	7	8	9	10	
Cash sales	€ 431.982,00	€ 839.965,00	€ 1.679.930,00	€ 3.359.860,00	€ 5.879.755,00	€ 8.399.650,00	€ 13.439.440,00	€ 23.039.040,00	€ 32.638.640,00	€ 40.318.320,00	€ 130.026.582,00
Crowdfunding	€ 50.000,00				€ 50.000,00	€ 50.000,00		€ 50.000,00			€ 200.000,00
Total Cash Receipts	€ 481.982,00	€ 839.965,00	€ 1.679.930,00	€ 3.359.860,00	€ 5.929.755,00	€ 8.449.650,00	€ 13.439.440,00	€ 23.089.040,00	€ 32.638.640,00	€ 40.318.320,00	€ 130.226.582,00
Cash Paid Out											
Marketing	€ 4.050,00	€ 7.875,00	€ 15.750,00	€ 31.500,00	€ 55.125,00	€ 78.750,00	€ 126.000,00	€ 216.000,00	€ 306.000,00	€ 378.000,00	€ 1.219.050,00
Materials and supplies (in COGS)	€ 291.054,24	€ 565.938,80	€ 1.131.877,60	€ 2.263.755,20	€ 3.961.571,60	€ 5.659.388,00	€ 9.055.020,80	€ 15.522.892,80	€ 21.990.764,80	€ 27.165.062,40	€ 87.607.326,24
Warehouse (bought after 4 years)				€ 261.000,00							€ 261.000,00
Taxes and licences	€ 10.095,37	€ 19.947,72	€ 40.231,99	€ 80.800,52	€ 141.653,31	€ 202.506,29	€ 324.211,87	€ 556.032,03	€ 787.852,19	€ 973.308,32	€ 3.136.639,59
Wages (less emp. credits)	€ 89.460,00	€ 173.950,00	€ 347.900,00	€ 695.800,00	€ 1.217.650,00	€ 1.739.500,00	€ 2.783.200,00	€ 4.771.200,00	€ 6.759.200,00	€ 8.349.600,00	€ 26.927.460,00
Total Cash Paid Out	€ 394.659,61	€ 767.711,52	€ 1.535.759,59	€ 3.332.855,72	€ 5.375.999,91	€ 7.680.144,29	€ 12.288.432,67	€ 21.066.124,83	€ 29.843.816,99	€ 36.865.970,72	€ 119.151.475,83
Cash on hand (end of year)	€ 87.322,39	€ 72.253,48	€ 144.170,41	€ 27.004,28	€ 553.755,09	€ 769.505,71	€ 1.151.007,33	€ 2.022.915,17	€ 2.794.823,01	€ 3.452.349,28	

Figure 7 Cash flow statement

A cash flow statement is an important financial tool that provides information about the incoming and outgoing cash of an organization. Looking at SolHavn´s incoming cash, one can identify the cash generated through sales, based on the expected sales, that were presented earlier. In addition, one can identify additional cash inflows every couple of years, due to crowdfunding to raise additional capital for the company.

Looking at the outgoing cash of the company, major aspects are the marketing costs, the costs of goods sold (COGS), taxes, and wages that the company has to pay. As SolHavn is expected to only have fewer orders in the first three years, a warehouse to store the material will not be needed yet. This is possible due to the fact, that the company will start with a just in sequence (JIS) supply chain model, where the goods will be delivered right on time and only when needed. As sales are expected to rise in the fourth year, the company will buy a warehouse to buy bigger amounts and store additional materials.

12.6 Scenarios

Scenario:	Year_1	Year_2	Year_3	Year_4	Year_5	Year_6	Year_7	Year_8	Year_9	Year_10
Optimistic	50.176	101.545	204.284	409.761	717.976	1.026.192	1.642.623	2.464.531	3.491.916	4.313.824
Expected	35.793	70.724	142.641	286.475	502.225	717.977	1.149.478	1.971.386	2.793.294	3.450.820
Pessimistic	25.519	50.176	101.545	204.284	358.391	512.500	985.097	1.478.242	2.094.672	2.587.817

Figure 8 Profit scenarios

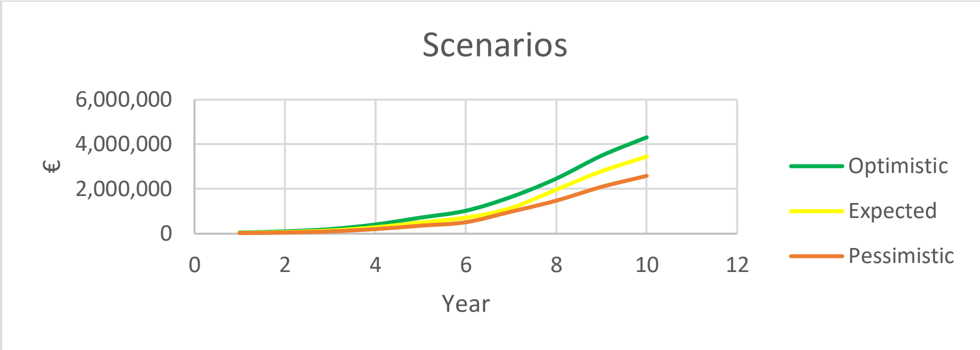


Figure 9 Graphic representation of scenarios

This graphic provides an overview of the development of the three potential outcomes of SolHavn for each year. It shows the expected profits for each of the optimistic, expected, and pessimistic scenarios of the business.

13 Business sub-questions

13.1 What is the most optimal location and partnering company that drives the highest demand for electrical bikes?

As the group´s project is focusing on sustainable energy and working only with the use of solar power, it is of high importance to find the most fitting location for this project. Not only does the chosen location need to have a high demand for electrical bikes and bike-sharing companies, but also fits the environmental requirements such as enough sun available to charge the bikes.

As a first step to deciding on where to base the project, the group had a look at European countries with the highest average sun hours per month. Based on research, it was identified, that Spain, Italy, and France are the European countries with the highest average sun hours in Europe, with the highest of 349 average sun hours in Alicante, Spain, dividing it into around eleven sun hours every day (Chang, 2022). Looking at France, a majority of the sun is in the southern part of the country, leading to limited possibilities of expansion and therefore is not suitable for the project.

After identifying the sunniest places within Europe, the project group had a look at the current market sizes for shared bikes within each of the countries. In 2018, over 350,000 people subscripted to different bike-sharing companies (Observatorio de la Movilidad Metropolitana, 2020). At the same time, Italy already had over 2.2 million subscribers for bike-sharing companies (Statista, 2022).

Besides looking at the existing market size in the different countries, it is also important to look into additional aspects that are of value for the project and the group. One of these aspects is the use of electrical bikes in both countries, as the project is focusing on these types of bikes. In Spain the electrical bike market has been rapidly growing over the last few years, leading to more than 1.2 million units in 2019 and an increase of nine percent market share compared to the previous year (Asociation de marcas y bicicletas de espana, 2019). The electric bike market in Italy on the other hand is rather stagnating and there were only around 275,000 electrical bikes in 2019 (Masperi, 2021). Due to the limited interest in electric bikes in Italy, the project group decided to go with Spain for the charging stations, as it offers the optimal climatic and infrastructural requirements for the project. The weather in Spain offers optimal conditions for the solar panels and there is an overall high interest in shared transportation methods and electric bikes.

After identifying the optimal country for the project, the group did some further research on the best city in Spain to start the project. It is important to choose a fitting town to ensure a successful start of the project and create a strong base for future expansion into other cities and countries. As average daily sun hours are quite similar all over Spain and there are no major peaks or minimums (Poo, 2020), the average sun time is not sufficient enough to decide on one city within Spain.

During in-depth research on the bike rental market in Spain, it was identified, that in Barcelona a majority of the market is placed. With over 113,000 subscribers and 15,000 docking stations in 2018 (Metropolitana, Observatorio de la Movilidad, 2020), Barcelona stands out from other Spanish cities and offers the best basis for the project. The city of Barcelona is offering one of the biggest fleets of electrical bikes in the city and actively supports sustainable transportation projects (Area Metropolitana de Barcelona, 2022).

13.2 What are potential substitutes for electrical bikes?

To successfully establish a business, it is important to be aware of substitutes that might attract potential customers more and take them away due to better competitive advantages. By identifying these substitutes, one can perfect the business strategy and create an even bigger competitive advantage. Based on the previously done Porter´s five forces analysis of the business environment, one can see that the threat of substitutes for e-bikes is at a high level. Since more and more innovations are being released to the market and businesses come up with more creative ways to attract potential customers.

One major substitute for e-bikes is classical public transportation methods, such as buses and trains. In most cities, the classic public transports have a well-established network around the city and a wide and consistent customer base. Consumers have known the system for a long time and are used to it and how it works. Also, the increasing usage of electric and more sustainable vehicles is another advantage. Though the classical transportation methods have a wide customer base, they are also bounded to schedules and fixed routes which leads to less flexibility for the consumer. In a time where freedom and flexibility are valued highly, this is a big disadvantage for busses and trains.

Another main substitute for e-bikes is electrical scooters. Similar to e-bikes, they offer the same great range of flexibility, sustainability, and prices. Further, e-scooters have been present for longer in the transportation market and are therefore more established and can be found in more places, compared to e-bikes (Hinchliffe, 2017). Another feature that can be seen as either positive or negative compared to e-bikes, is that the user does not have to exercise while using the electric scooters. Though there is a lot of controversy about electric scooters, and their actual support of sustainable transportation and spread over the cities, electric scooter is one of the biggest and most threatening substitutes for e-bikes.

Private transportation methods such as cars or own bikes or walking somewhere are also potential substitutes and should be taken seriously. Due to increasing environmental awareness and rising parking and gas prices, cars are not the biggest threat of substitutes. Walking to places is an environmentally friendly and completely free way of transportation but is mainly only suitable for short distances without a lot of things to carry. Therefore, it is not a major substitute for e-bikes as they are more used on medium-distance routes. At last, using one´s bike is a major substitute for renting an electric bike from a company. In the long-term view its cheaper, when used regularly, it is always available and has no limitations when it comes to leaving the city center for example.

In conclusion, it can be said that there is a wide range of substitutes for electric bikes. Especially e-scooter companies have acknowledged a big boost over the last couple of years. But also, the classical ways of transportation, either by bus, train or the own bike are substitutes that should be taken seriously. With innovations, trends, and governmental regulations, the transportation sector is a fast-evolving and changing market that needs to be monitored closely to not oversee any potential uprising substitutes and stay ahead of the competition.

13.3 What are the key success factors of the product?

In today’s market where the competition is stiff and customers have several other competitors they can go to, it is important for SolHavn to have important elements required to compete in its target markets. The key to success in business is about focusing on producing greater results and performance from the same activities, the same capital, and the same people. It is about identifying, improving, and taking full advantage of all the overlooked, hidden, and underperforming opportunities that exist within the business. About getting substantially more for less, optimizing and multiplying the results in the business key success factors with minimum effort, expenses, and risk.

A critical success factor (CSF) is a specific area or element that a team, department, or business must successfully implement and focus on to achieve its strategic goals. Successful implementation and execution of critical success factors in business create value for products and services and generate positive outcomes. The importance of CSFs lies in the fact that it guides a business. Monitoring and defining a critical success factor are the only way of knowing what the deliverables demand, otherwise they remain hypothetical. Of course, everyone in the team or the organization must first be accustomed to the critical success factors definition.

SolHavn puts people above all. The company strives to make sure the work environment is pleasant for all and continuously seeks to create a better team culture. In doing so, the company seeks to create a familial atmosphere because they recognize employees spend much time away from their actual families. SolHavn also recognizes the importance of establishing industry contacts. Although still in the first phase of development, the company has a highly ambitious to spread out and ultimately create a charging infrastructure throughout all of Europe. Networking and establishing sales relationships with potential customers are crucial. Once acquiring new customers, however, SolHavn makes sure to maintain relationships in order to establish a good relationship in the market and stand out from the competition.

Due to wanting to maintain good standing in the industry, the company also places great importance on manufacturing quality products. The charging stations are constructed using quality materials that are economical and will protect the e-bikes from both potential robbers and the effects of weather. The structure also maintains a low-cost design which will drive down costs for the customers and place SolHavn in a greater standing. The charging stations will be constructed on-site and therefore, eliminate the need for plant or factory locations which would attribute a much higher cost to the overall price. Also, SolHavn employees are skilled laborers that can get the job done as fast as possible while maintaining the quality and integrity of the overall structure.

13.4 How can potential customers be convinced of the product?

SolHavn creates states of the art charging stations that are driven by innovation and spearhead the movement toward sustainable energy. Solar panels are the primary means of power in order to harvest solar energy and run fully independently of the electrical grid. On days when there may not necessarily be enough solar energy to power the station, the battery is designed in a manner to store the excess energy and utilize the reserve when needed. The overall energy cost will be much lower than traditional electrical power and therefore drive down costs for the customer over a prolonged period of time.

The high-quality materials are ensuring that the customer's bikes are well protected. The e-bikes are expensive, especially when considering large amounts, therefore it is of no trial matter making sure they are protected. E-bikes face potential danger from vandals or people simply mistreating the e-bikes when they see them on the streets. Often the investment of the bike can quickly turn sour due to being set outside with no one to protect them. Not only people, but the weather itself can bear great problems to the bikes. Due to their electrical components, the bikes are more sensitive to weather conditions than traditional bikes. The charging station also is protected via automatic lock and can only be opened with a pin code. The highly resistant material can withstand any blunt force trauma and additionally, the installation of surveillance cameras to monitor both the station and electric bike from potential theft and vandalism.

SolHavn also will provide continuous service of the charging station once it has been constructed and purchased to eliminate any headaches for the customer and best ensure the charging station lasts for as long as possible.

Also, not just the product itself, but the company's values. SolHavn places monumental importance on the sustainability aspect of the project. The charging stations are eco-friendly and designed to last indefinitely and independently due to the nature of renewable energy. This gives great benefit not only to the customer but also to the environment and world as a whole. SolHavn does not just sell a product, but also a way of life. Sustainability improves the quality of life, protects the ecosystem, and preserves natural resources for future generations. In the corporate world, sustainability is associated with an organization's holistic approach, taking into account everything, from manufacturing to logistics to customer service. Going green and sustainable is not only beneficial for the company; it also maximizes the benefits of an environmental focus in the long term. Regardless of who we are, where we live, and what we do, we all have a moral obligation to each other, our future generations, and other species to sustain the planet. Our present choices and actions have huge long-term impacts on future generations. Practicing sustainability ensures that we make ethical choices that bring a safe and livable future to everyone. If we deplete the resources of the Earth, future generations will be depleted.

13.5 How can the necessary capital be raised to fund the project?

The initial investment is an important capital of a company, as it allows it to start with the business, do effective marketing, and attract potential customers. Especially for start-ups, such as Solhavn, which require a higher initial investment for materials and targeting customers, it is important to have access to the needed money in the best and quickest way possible. One way to gain the needed capital is through crowdfunding, which is a popular and widespread method for start-ups to raise money for their company.

Crowdfunding is a way to raise the needed capital through the donations of others (European Comission, 2022). It is based on the concept that a huge number of people donate small amounts of money for a specific cause or project. A major advantage of crowdfunding compared to traditional funding, for example through a bank loan, is that the borrower usually does not have to pay back any money to the lenders, as they donate the money voluntarily instead of loaning it and expecting the money back with an interest (European Comission, 2022).

Looking at the company, one can say that Solhavn has a high chance to get the needed capital raised through crowdfunding, due to several facts. At first, the company is combining two rising trends, sustainability, and transportation. As a lot of end consumers are interested in these topics and want to change their future, they are more willing to invest in a company that is tackling these problems. Especially those who use bike-sharing companies regularly are more likely to take part in crowdfunding.

Another advantage is, that the people who donate money can decide on their own how much they want to give and do not have to spend big amounts of money. By only donating a smaller number, more people are willing to participate as it does not affect them as much but still allows them to help if they want to. The more people give small amounts of money, the faster Solhavn will hit its target of the needed capital.

At last, crowdfunding is a great way to raise capital for a company like Solhavn, as it is relatively cheap to reach out to a lot of people. through various social media activities, the company can reach more and more supporters over time. Once donated some money, the person can also share his or her support via social media and make even more people aware of the company and the help it needs. In this way, the organization´s crowdfunding campaign can quickly spread and reach more and more people.

After a successful start through money raised by crowdfunding, the company will gain a majority of its needed capital through sales to the customers. With this money, the materials for the stations can be bought, the assembly of the stations is ensured and SolHavn can invest in attracting further potential customers. If additional capital will be needed, the company will again make use of crowdfunding or potentially sell shares of the company in the future once the company has grown.

Mechanical part
14 Theory/literature survey

A general study of how a PV system works, how photovoltaic energy is created, and what kind of electrical connections and components are present in a photovoltaic system is required to ensure the project's successful completion.

14.1 Theory abstract

Solar energy is a readily available renewable energy source. Solar radiation can be converted into electricity by photovoltaic systems and can be used to heat water in thermal systems. Photovoltaic (PV) solar power systems use cells that use solar light photons to strike the doped semiconductor silicon to produce electricity.

Solar radiation of the sun

The sun is a source of electromagnetic energy, the thermonuclear fusion between the hydrogen and helium atoms produced in its interior causes it to lose matter, which is transformed into energy in the form of electromagnetic radiation, known as **solar radiation.** The solar radiation is divided in:

- Direct solar radiation: unscattered radiation from the sun
- Diffuse solar radiation: radiation from the sun that changed direction due to interaction with the atmosphere
- Reflected solar radiation: radiation that strikes a surface after having first reflected off another surface.
- [1]Irradiance: the amount of light energy that strikes a square meter. W/m^2

Solar radiation is the integral of solar irradiance over a period of time (Wh/m^2).

PV system

A photovoltaic system (PV System) generates electrical energy from solar energy. The photons of solar irradiance that fall on the free electrons of the PV cell mobilize them and

[1] *The distance between the sun and the earth is variable but it is assumed that an average value of 1367 W/m2 arrives before reaching the earth's atmosphere. When these electromagnetic waves reach the atmosphere, we will have three types of solar radiation.*

cause an electric current to flow. PV cells are made up of two layers: free electrons and holes.

Resistance of Materials

The study involves the calculation of the static force on a fixed element of the isostatic and hyperstatic structure. The concept of determining if an interconnected element of a building with a rigid or moving end are capable to withstand load for a long period of time before collapsing without experiencing any other deformation. A proper design structure would be to distribute the acted force equally and should be in equilibrium with another joint frame or element. The type of internal force would be axial force, shear stress, and bending moment.

The axial force is the force that acts normally or axial direction on the surface of a cross-sectional area. It tends to push or elongate the body of the material or in other terms compression and traction force.

The shear stress acts tangentially on the surface of the cross-sectional area, tending to slide or glide away from each other of the section by separating or cutting it. Next, the bending moment is when external force or moment acts on the plane direction of the section. It tends to rotate laterally the element by curving and flexing it.

Lastly, the torsion moment defines as the tendency of the element to rotate itself when the external force act tangentially on the cross-sectional area of any given element. The convention of signs needs to be considered for these forces during the calculation (Enguita, 2019).

14.2 Main components in electrical PV systems

The many components of a solar system will be defined mostly by whether it is connected to a utility grid and the sort of load current. If the system's load requires AC current, an inverter is required to convert the DC current produced by the solar panel. If the system is connected to the grid, an inverter will be required to feed the generated electricity into the grid utility.

Inverter

An inverter is an electronic device that has the function of transforming a direct current (DC) into alternating current (AC) at a certain voltage and frequency, using a direct current source. The inverter is normally used in photovoltaic systems where the electricity produced by the modules is converted into alternating current to power all equipment.

Controller

As the name implies, the charge controller is in charge of constantly monitoring the level of charge of the batteries as well as controlling the strength of the charge in order to increase the life of the batteries. Depending on the state of the batteries, the controller regulates the energy input from the solar panels to the batteries. The charge controller adjusts the charge of the batteries as the power from the solar panels rises to avoid overcharging. This prevents the batteries from being damaged by excessive voltage.
There are two types of controllers: MPPT (Maximum Power Point Tracking) and PWM (Pulse-Width Modulation). In summary, the MPPT oversees working on the photovoltaic panels' input voltage to extract the maximum power or limit the power in the "absorption" and "floating" phases, while the PWM functions as a switch between the solar panels and the battery.

Battery

Solar batteries are electrical accumulators for storing the electrical energy generated by a photovoltaic panel in a solar energy installation. Batteries are used to provide electrical energy to the system when the photovoltaic panels are unable to generate it. For example, during the night or at times of low luminosity.

Stepdown

It is a controller that is responsible for lowering the DC-DC current.

(DITEK, n.d.)

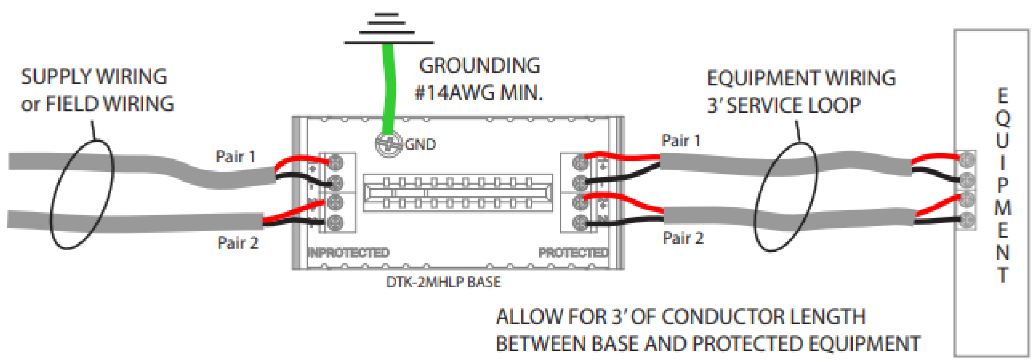


Figure 10: Stepdown installation

Grid-Connected Solar Electric System

Grid-Connected Solar Electric System is a book written by PV experts, Susan Neill, and Geoff Stapleton. It is a textbook focused on PV system design and installation, with a wealth of information on system components, aspects of design, and PV cell and module operation. Solar energy is developing energy and can be used on a wide variety of scales as the sun is free energy, from small home systems to utility-scale solar farms. It can be implemented in an electricity grid, meaning that in times of low solar energy, users can continue to use their equipment without any interruption; on the other hand, if the amount of electricity is greater than what the consumer needs, it can be sold to the national electricity grid. The book is the ideal guide for students, as well as electricians, architecture, builders, homeowners; everyone who needs a clear introduction to grid-connected solar electric technology.

14.3 Main software for design and calculation

Homer Software

HOMER Pro, also known as HOMER (Hybrid Optimization of Multiple Electric Renewables), makes it easier to evaluate designs for both off-grid and grid-connected power systems. The National Renewable Energy Laboratory in the United States created HOMER, a free software application. This software application is used to build and analyze off-grid and on-grid power system solutions for remote, stand-alone, and distributed generation applications, both technically and financially.

Mathcad

A licensed computer program designed for mathematical calculation involved various disciples of science and engineering such as civil, mechanical, mechatronic, electrical, and lastly chemical. The program helps the user to solve a complex mathematical equation and document the results in a spreadsheet. Furthermore, it enables the user to change the parameter or variable of the calculation with ease using a certain available command in the software. The software was developed by Mathsoft PTC and is suitable for both industry and education purposes. The simple interface facilitates the user to identify and analyze the mistake or error in the vital calculation by highlighting it.

AutoCAD

Inventor 2022 is the software used for the overall mechanical design of the project. It is a licensed commercial computer-aided design software that facilitates the drawing of 2D diagrams layout and modeling the 3D design with precise dimensions for the users. Inventor is one of the available software that comes along with Autodesk, Recap 360, and DWG TrueView from the main package provided by the company AutoCAD. In addition, other features included are a toolset for creating, editing, simulating, and integrating design which can be applied to different engineering fields like architectural, electrical, and plumbing. The friendly interface and the various commands which have few similarities with the other applications make it more flexible to use. The conversion of files is necessary when utilizing different software due to the incompatible format file. The units established in the software during the development of design are centimeters and degree angles.

WinEva version 7.04

Free open-source software developed by the architecture department of the University Polytechnic of Catalunya, Spain. The program's main purpose was to facilitate calculating the elastic deformation and stresses produced in a 2D sketch of bar structures that are subjected to certain conditions. It allows the user to create a linear bar of any given real structure on a plane and analyze the corresponding value of force such as axial, bending moment, or shear stress. In addition, it also allows the user to simulate the 3D design of common structures such as continuous beams, orthogonal frames, framed structures, and trusses. The users are also capable of modifying the mechanical properties of the beam such as the modulus elasticity, density, and the coefficient of linear expansion.

15 Methods

To dimension a solar system, a preliminary assumption must be taken, the exact load that the system will need is not known but after selecting some of the components and the main load that will be charging the electrical bikes, a number close to the real one can be calculated.

For the first scenario, the E-Bike Charging Station (ECS) is a self-sufficient charging station equipped with 10 bicycles, which uses solar energy to produce and store the electricity necessary for the station's complete independence from the national electricity grid. It is an off-grid PV system equipped with a storage battery to ensure the autonomy of the station even in the event of consecutive cloudy days.

The ECS will require lighting at night, which will be provides by two LED lights. For the possible renting consumer, to interact with the system, a display is necessary. All the electronic circuits, as well as their elements, are not taken into consideration in this project as the current bicycle rental service of Barcelona municipality has its own system.

While the bicycle is charging a red signal light will be on, and when the battery of the bike is completely charged, a green signal light will be on.

The e-bike model chosen for the ECS fleet is the LEGEND MILANO (VG Mobility Trade S.L., n.d.). The general technical specifications of the bike battery are 36V integrated Li-ION battery, capacity: 400 WH, 10.4Ah. The technical datasheet for all the elements can be found in the C appendix.

It is important to introduce two different scenarios, the worst one and the better one, to fully understand how the demand and the production of energy are related to the variation of the hours of sun.

The worst scenario is set during the winter when the daily light hours are few and it negatively affects the production of energy; on the other side, the best scenario is set during the summer when the sun allows producing a greater quantity of energy than can be easily stored thanks to the storage battery or sold to the national electricity grid.

15.1Winter Scenario OFF GRID

15.1.1 First load assumption

In Barcelona, during the winter, the hours of sun in a day are approximately 9, with the sunrise at 8:13 am and the sunset at 5:24 pm on the shortest day of the year.

(Timeanddate, 2021)

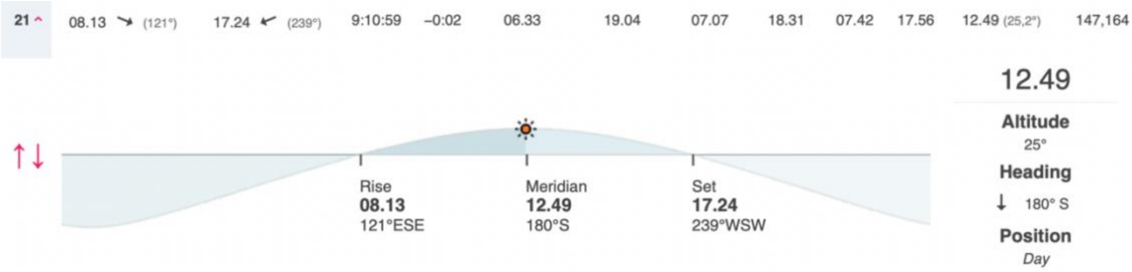


Figure 11: Sunrise and sunset times in Barcelona in December

In winter, the lighting will be 15h at night, the display will be on 24H as the signal lights. The consumption of the bikes depends on the times that the bikes will be fully charged during the day, the batteries of the bikes are fully recharged on average 2 times a day, 8 hours per charge, to guarantee an autonomy of 160 Km. (Bicibox, 2022)
The daily load of every component has been calculated in the D appendix.

Adding all the values obtained, it is possible to easily calculate the total consumption of electricity in a day during the winter in Barcelona which is 9 kWh/Day.
Since the overall load is more than 3 kWh, the voltage of the E-Bike Charging Station is 48 V. (Dihrab, 2021). If it is possible for the system to use a higher voltage system, like for example 96V, but for security reasons in the installation and operation 48V system is enough.

15.1.2 Equivalent Solar Hours

To find the minimum number of solar panels of the array it's necessary to find the value of the load current and nominal current Ip starting from the total consumption and the voltage of the system.
The nominal current is equal to 187 Ah, obtained by dividing the total consumption of electricity in a day by the voltage of the system; whereas the nominal current is 51Ah, obtained by dividing the load current by the ESH calculated in Figure 12.
The ESH is the "equivalent solar hours", also known as PSH, "peak sun hours", and it is one of the most important parameters to know to size a photovoltaic system. It represents the amount of energy per day that reaches a certain location on the earth's surface from

the sun; more precisely, it is the number of hours per day during which the average solar irradiance is 1000 $Watts$ per square meter (W/m^2).
To obtain the ESH value is necessary to know the data of solar irradiance in Barcelona that can be found on (Commission, s.d.) uploaded in the c appendix.
Once all data has been collected, it's possible to proceed by considering the months in the last 5 years where solar radiation is minimal, as is represented in Figure 12, thus assuming the worst-case scenario. The ratio between the average solar radiation and the average of the days of the months taken into consideration provides the value of the ESH, the equivalent solar hours, equal to 3,66.

WINTER

Year	2015	2016	2017	2018	2019	2020
Month	FEB	OCT	DEC	NOV	DEC	NOV
Direct Normal Irradiation(kWh/m2)	127,96	97,2	110,52	104,39	113,66	113,98
Days	29	31	31	30	31	30
Temperature	11,5	18	9,7	13,4	12	14,3

Avg irradiation :	111,285
Avg days:	30,33333
ESH:	3,668736

Figure 12: Lowest solar radiation from 2015 to 2020

15.1.3 Number of minimum solar panels

There are two main techniques for wiring together solar panels, and each has different characteristics. The wire up of the ECS solar panels can be in parallel or series. The solar panels produce DC, the overall system voltage will be the sum of the voltage produced by each panel if the solar panels are connected in series, and the current will remain constant. The main downside of this connection is that the energy production would be greatly reduced due to shadowing or a malfunction of one of the panels.
On the other side, if the wire up is in parallel, instead of the voltage remaining constant, the current of the ECS will be large, therefore the security of the high current wiring must be considered.
Knowing the benefits and drawbacks of the various distribution methods, the chosen installation will be parallel.

The minimum number of modules to be connected in parallel is calculated starting from the datasheet of the solar panels (b appendix). The maximum power current of

“LUXPOWER SERIES 4 360-380W Mono” is $Im = 10.76$; the minimum number of solar panels can be calculated by dividing the nominal currentI_p by the maximum power current. All calculations are done in the appendix.
To supply the consumption demand of the E-Bike Charging Station during the winter in Barcelona the PV array must be composed of at least **5 solar panels**.

15.2Summer OFF-GRID

In Barcelona, during the summer, the hours of sun in a day are approximately 15, with the sunrise at 6:18 am and the sunset at 9:28 pm on the longest day of the year.
(Timeanddate, 2021)

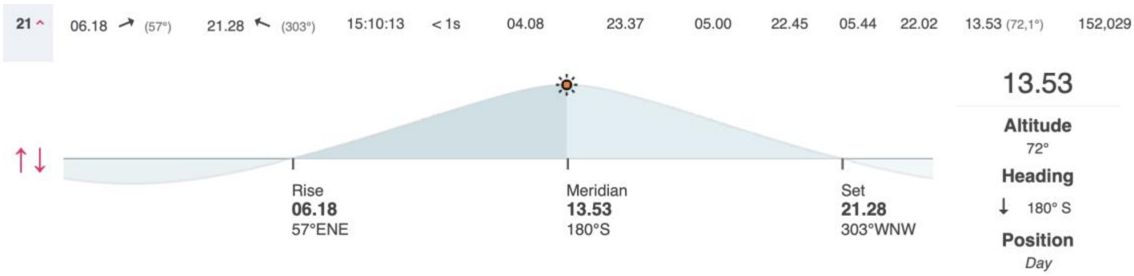


Figure 13: Sunrise and sunset times in Barcelona in June

To get an overview of how the ECS works, a study of the highest month of energy production during the summer in June has been carried out. The load will be relatively comparable to that of the winter months, with the exception that there will be long hours of sunlight throughout the day, therefore the lighting demand will be lower.
The 2 led lights will work for 9 hours compared to the red and green lights and the display will work for 24 hours. The lightning consumption is 0,376 Wh/Day and the display consumption is 0,384 kWh/Day.
The consumption of the batteries of the bikes does not vary if the average number of recharges is the same as in the winter; the consumption of the batteries is still 8 kWh/day. Adding all the values obtained, it is possible to easily calculate the total consumption of electricity in a day during summer in Barcelona, that is 8,76 kWh/Day.
Following the same steps as in Chapter 15.1.1, the chosen system voltage is 48V. In the same way, as in the preceding scenario, the load current I_l, nominal current Ip, and ESH must be known during the summer in Barcelona; the load current is 182,51 Ah and the nominal current is 26,22 Ah. The ESH is calculated like the previous case.

To obtain the ESH value is necessary to know the data of solar irradiance in Barcelona that can be found on (Commission, s.d.) attached on c appendix. Once all data have been collected in Figure 14, it is possible to proceed by evaluating the months in the last 5 years with the highest solar radiation, assuming the best-case scenario. The ESH, or equivalent solar hours, is equal to 6,96 when the average solar radiation is divided by the average of the days of the months taken into account.

SUMMER

Year	2015	2016	2017	2018	2019	2020
Month	JUN	JUL	MAY	JUL	JUN	JUL
Direct Normal Irradiation(kWh/m2	214,01	219,55	210,27	217,89	210,17	210,45
Days	30	31	31	31	30	31
Temperature	22,1	23,8	17,8	24,8	20,6	24,1

Avg irradiation:	213,7233
Avg days:	30,66667
ESH:	6,969239

Figure 14: Highest solar radiation from 2015 to 2020

The maximum power current of "LUXPOWER SERIES 4 360-380W Mono" is I_m=10.76. To supply the consumption demand of the ECS during the summer in Barcelona the PV array must be composed of at least three solar panels. Even in the best-case scenario, The ECB requires a minimum of 5 solar panels to work constantly throughout the year.

15.3 Temperature Effect

To be sure that the solar panels are suitable for the installation, it is also important to consider the effect of the temperature on the relative modules; indeed, the solar radiation hitting the modules does not produce only electricity but also heats the modules.
On a sunny day, for instance, it is not uncommon for a PV module to reach over 70°C.

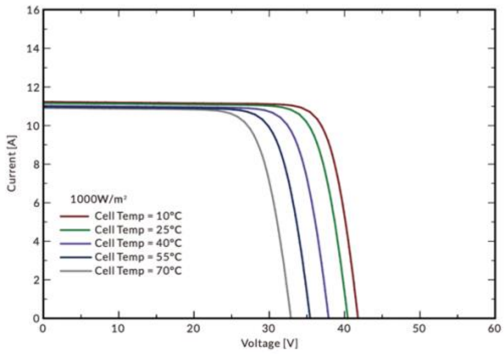


Figure 15: Temperature effect on the solar cells

If the temperature increases, the open-circuit voltage decreases rapidly while the short circuit current increases slowly, which means that hot temperature negatively affects power output; likewise, cold temperatures increase the power output due to the increase of the voltage, as can be seen in Figure 15, taken from the datasheet in the b appendix.

$$P = V \cdot \mathrm{I} = \mathrm{Voltage} \cdot \mathrm{Current}$$

It is therefore important to consider the effect of temperature on the performance of solar panels, the reduction of the output from a PV array due to hot temperature, and the increase of the voltage due to cold temperature, which must be accurately calculated to ensure that it cannot exceed the inverter's rating.
For safety reasons, the output voltage of the string must be below the maximum system voltage (48V). (Stapleton & Neill, 2012).
To calculate maximum and minimum operating voltage is necessary to know maximum and minimum PV cell temperatures, as well as maximum and minimum temperatures at the installation site, known as the maximum and minimum ambient temperatures.

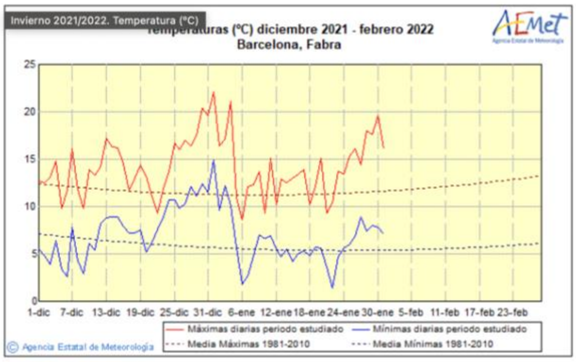


Figure 16: Temperature variation throughout the winter in Barcelona

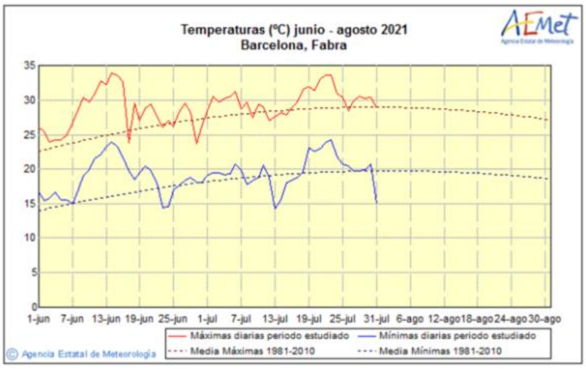


Figure 17: Temperature variation throughout the summer in Barcelona

(Meteorologica, s.d.)

In Barcelona, the ambient temperatures in one year can vary from $2°C$ to $34°C$ but to avoid the risk of malfunction due to uncommon atmospheric phenomena It's important to introduce a tolerance margin of $5°C$; therefore, for safety reasons, the temperature range is $-3°C$ to $39°C$.

From ambient temperatures, PV module cell temperatures can be calculated.

To design PV arrays, as well as to select the correct modules, an approximation is often used for the calculation of the cell temperature:

$$cell\ temperature = ambient\ temperature + 25°C$$

(Stapleton & Neill, 2012)

The minimum operating cell temperature is the same as the minimum ambient temperature because the PV module will not have heated up early in the morning when it

starts to produce electricity; likewise, the maximum operating cell temperature is calculated using the approximation introduced before.
In Barcelona the maximum and minimum cell temperatures are as follows:

$$Minimum\ cell\ temperature = Minimum\ ambient\ temperature = -3°C$$
$$Maximum\ cell\ temperature = 39°C + 25°C = 64°C$$

Using the voltage temperatures coefficient data obtained from the datasheet in the b appendix, it is possible to calculate the maximum and minimum output voltage of the array to ensure that the output voltage of the string must be below the maximum system voltage (48V).
The range of values of the module voltage can be calculated as follow:

If the temperature is lower than $25°C$:

$$Voltage_{at\ X°C} = Voltage_{at\ STC} + \left[\gamma_v \cdot (T_{X°C} - T_{STC})\right]$$

(Stapleton & Neill, 2012)

- If the temperature is higher than $25°C$:

$$Voltage_{at\ X°C} = Voltage_{at\ STC} - [\gamma_v \cdot (T_{X°C} - T_{STC})]$$

(Stapleton & Neill, 2012)

Where:
$Voltage_{at\ X°C} = voltage\ at\ the\ specified\ temperature\ (X°C)\ in\ volts.$
$Voltage_{at\ STC} = voltage\ at\ STC\ (from$ Solar panel $datasheet).$
$\gamma_v = voltage\ temperature\ coefficient\ in\, V/°C\ \ (from$ Solar panel $datasheet)$
$T_{X°C} = cell\ temperature\ in\ °C.$
$T_{STC} = temperature\ at\ STC\ in\ °C.$

The maximum voltage of the module is present at the minimum cell temperature and vice versa.

As it can be seen in the calculation of d and e ,the values of the maximum and minimum operating voltage are:

$$Maximum\ voltage = 45{,}12\ V$$
$$Minimum\ voltage = 29{,}16\ V$$

Maximum and minimum operating voltage of solar panels, $45{,}12\ V$, and $29{,}16\ V$, are below the operating voltage of the system, $48\ V$: the chosen module, “LUXPOWER SERIES 4 360-380W Mono”, meets the requirement of the operating voltage.

15.4 Battery sizing

To ensure continuous availability of electricity, a PV system must be adjusted for the potential that the solar panels do not produce enough energy at the point of demand, either because there is insufficient sunshine on a cloudy day or because the demand comes at night. In the following circumstances, we require a battery system to deliver electricity to the ECS. To size the required battery capacity, it is necessary to know the total load of the equipment connected to the charging station, the number of days of autonomy in the event of bad weather conditions, and the depth of discharge coefficient (DoD). As batteries degrade rapidly if allowed to discharge completely too often; therefore, a cut-off is normally imposed, so that the battery charge cannot drop below a certain percentage of full charge.
The minimum number of days of autonomy of the station in case of a fully recharged battery is two and the discharged cut-off limit is 30%, the DoD is 70%. Considering a standard value of 0.85 for battery losses, it is possible to find the required capacity of the battery:

$$Battery\ capacity = \frac{9\frac{kW\mathrm{h}}{Day} \cdot 2\ days}{0{,}85 \cdot 0{,}7 \cdot 48V} = 630{,}2\ A\mathrm{h}$$

(Dihrab, 2021)

The battery compartment of the charging station, therefore, consists of 3 “EBICK ULTRA 175” connected in a parallel configuration that can be seen in c appendix and Figure 18. The rated nominal voltage is 48V and the rated capacity is 840 Ah.

To be more accurate, the number of days of autonomy of the station in the case of a completely charged battery can be calculated using the same formula as before and modifying the value of the capacity, which is 840Ah. The ECS provides an autonomy of 2 days and 15 hours.

(Cecasa, 2022)

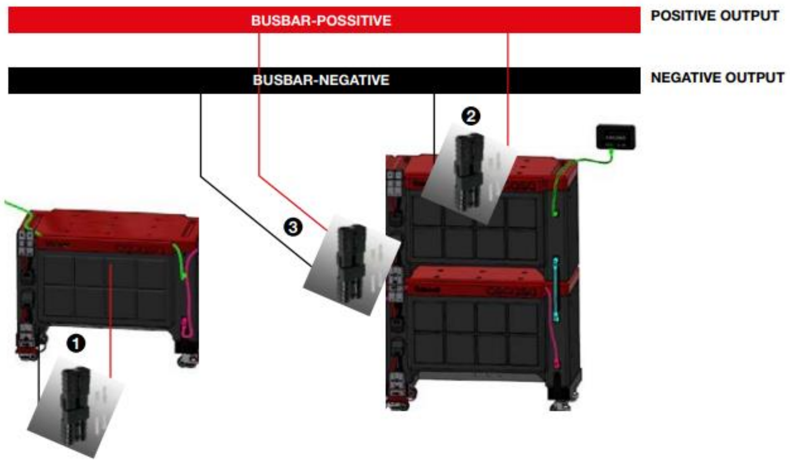


Figure 18: 3 Parallel configuration

The total power consumption of the battery is 40,32 kWh. To charge the storage battery is, therefore, necessary to size an additional PV system, following the same steps as in Chapter 15.1.1, to meet the needs of the new load introduced. Supposing to charge 15% of the battery every day, the new load to be taken into consideration to obtain the number of additional PV modules is 6 kWh/day more.

The additional number of photovoltaic panels to be added to the charging station to meet the consumption of the new load introduced is 3. (Calculations attached on f appendix).

15.4.1 Life of a battery

Batteries for a PV system must combine low cost, low maintenance and robust construction, long lifetime, high energy efficiency, and wide operating temperature. There is *no* type of battery fitting these requirements, so it is necessary to consider the advantages and disadvantages of different types of batteries *with* respect *to* the project. (Hanley, 2009)

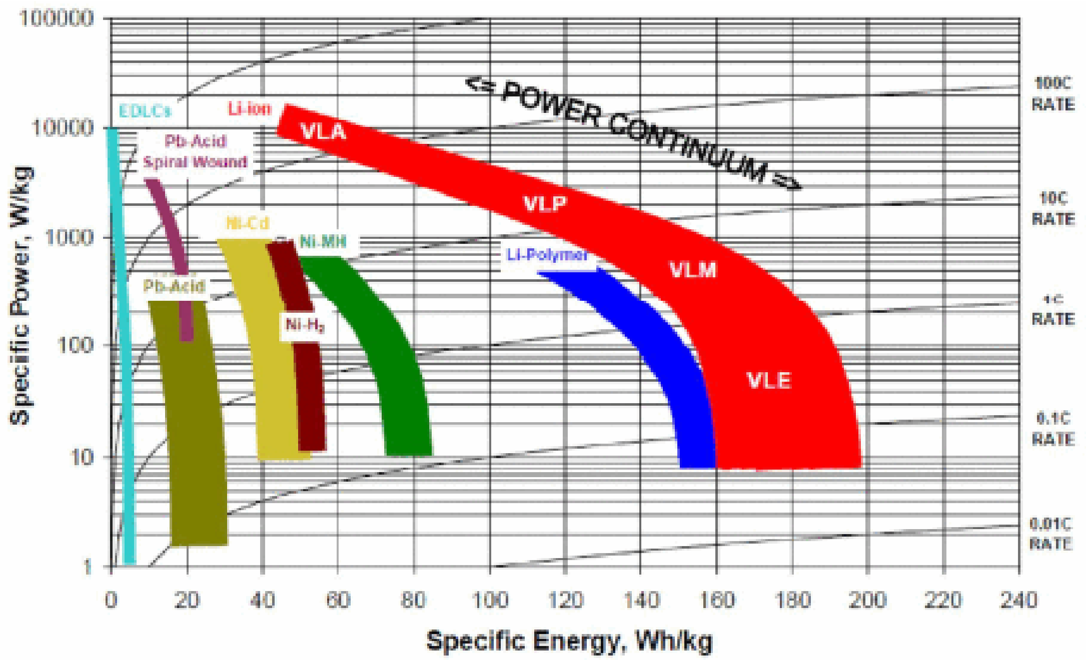


Figure 19: Specific Power/Specific energy of rechargeable cells

As can be seen in Figure 19 the Li-Ion battery technology is the one with better performance, due to its high gravimetric and volumetric capacity. The technology of the Li-ion battery selected is LFP. This battery can offer a long-time cycle life between the fifteenth years without maintenance and with the normal use of about 25 years (Cecasa, 2022).

15.5 Losses

Numerous factors negatively affect the efficiency, as well as the energy production, of a photovoltaic system: these factors are accounted for through a process called de-rating.

To calculate the correct amount of energy produced over a year and understand if the sized photovoltaic system can meet the energy needs, it is necessary to consider the de-rating factors.

The main factors that can influence the efficiency of the system are temperature, dirt, shading, the orientation of the modules, and the efficiency of each component of the circuit… (all the calculations about losses are attached in the g appendix) (Stapleton & Neill, 2012).

The effect of the temperature on the output depends on the module chosen for the array and the losses can be calculated starting from the technical datasheet of the solar panel, attached in b appendix, from the temperature coefficient. The de-rating factor of the temperature is 0,942, which corresponds to an efficiency of 94,2%.

Soiling losses are caused by the accumulation of dirt on the modules, which covers and shades the surface of the panel, reducing the power output. This factor is strongly correlated to the place of installation of the system; being Barcelona a large coastal city, the proximity to the sea, the salty environment, and the intense traffic affects the de-rating factor negatively. It is, therefore, possible to use a reduction in yield of 10% due to dirt, with a reduction in efficiency to 90%.

The manufacturer's tolerance loss is supposed 0% since it is not given on the datasheet of the modules; it's supposed 0% also the shading loss, assuming the building is completely unshaded.

The voltage drop loss is caused by the length and thinness of the cables and a maximum value of 5% can be assumed, with a de-rating factor of 0,95. To avoid and minimize voltage drop is important to use a larger cable, cheaper than adding additional modules to the array to compensate for the power loss.

The roof of the structure on which the solar modules are placed has an optimal inclination of 38°; so, the loss due to the optimal tilt angle is 0%, as can be seen in (González-González, et al., 2022).

Lastly, the efficiency of the MPPT is written on its datasheet of it; the de-rating factor is 0,975.

Multiplying all the de-rating factors is possible to obtain the total de-rating factor due to the system losses, equal to 0,785.

The total de-rating factor is so 0,785, which means that the system is 78,5% efficient and the system loss is 21,5%.

Source of loss	De-rating factor	Description
Temperature	0,942	As calculated in Total losses
Dirt/Soiling	0,9	Barcelona is a coastal area so losses due to soiling are assumed to be ∼10%
Manufacturer's tolerance	1	This is not given on the datasheet
Shading	1	Assume the array is unshaded
Voltage drop	0,95	Assume a voltage drop of 5%. (Stapleton & Neill, 2012)
Orientation and tilt angle	1	From (González-González, et al., 2022)
MPPT efficiency	0,975	The efficiency is given on the MPPT datasheet

Table 1:Losses of the system

(Stapleton & Neill, 2012)

15.6 System Yield

Once obtained the total de-rating factor, it is possible to calculate the total energy produced by the off-grid photovoltaic system used to recharge the bicycles in Barcelona. On average, for a year, Barcelona receives 5,31 peak sun hours per day (average between winter and summer ESH, respectively of 3,66 and 6,96) that, multiplied by the numbers of the days in one year, 365, it's possible to determine the annual irradiation equal to 1938,15 $\frac{kW\text{h}/m^2}{year}$.

Considering the PV's array rated power of 2,92 kW, as can be seen in h appendix, the total derating factor of 0,785 and the annual irradiation equal to 1938,15 $\frac{kW\text{h}/m^2}{year}$, is possible to find the total yield of the system equal to $4301{,}54\frac{kWh}{year}$, as it can be seen in i appendix. (Stapleton & Neill, 2012)

The *E-Bike Charging Station*, in one year, consumes: $3285\frac{kWh}{year}$ (j appendix)

As it can be seen, the annual production of energy covers the annual consumption of the charging station.

15.7 Electrical overview

The electrical circuit works just in direct current; therefore, the inverter is not necessary. The main circuit, as can be seen in Figure 20, is composed of an MPPT charge controller, 3 storage batteries, and two stepdown DC-DC converters.

In more detail, a Raspberry Pi controller also appears in the circuit, and it is used to carry out normal operations through the monitor, including locking and unlocking bicycles and turning lights on and off. (Chandra Mouli, et al., 2020)

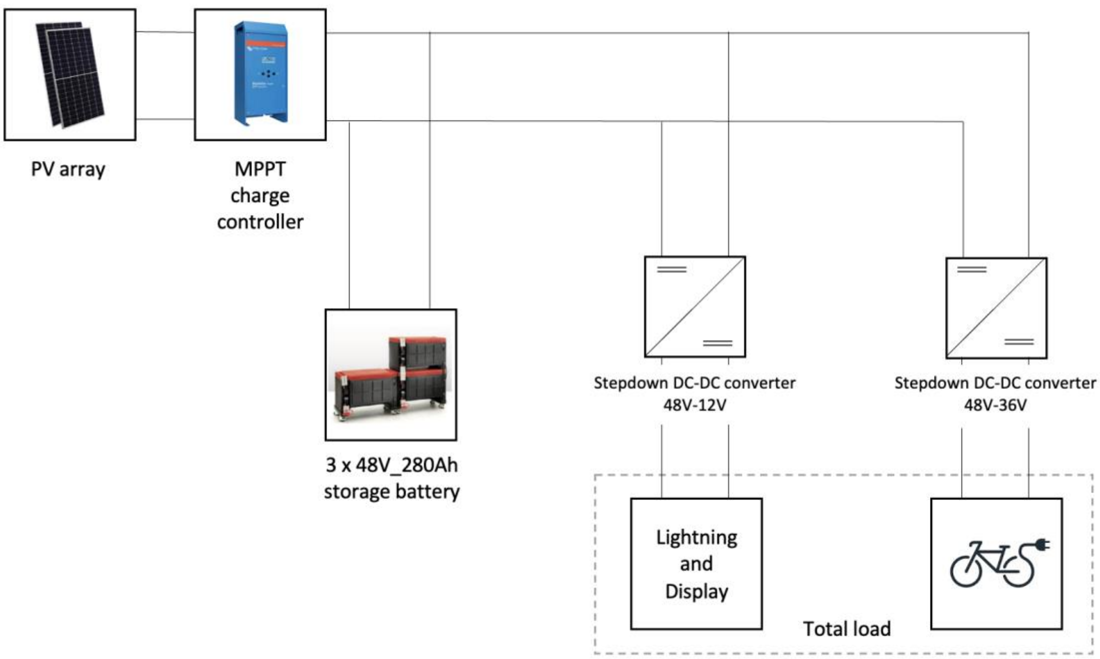


Figure 20: Electrical circuit

(Chandra Mouli, et al., 2020)

The MPPT is the acronym for Maximum Power Point Tracking; it is used to track constantly the point of maximum power that the panel can deliver at that moment thus optimizing battery charging, thanks to the higher charging current delivered to the battery and the wider input voltage range.

The battery compartment consists of 3 modular batteries connected in parallel with a nominal voltage of $48V$ and a nominal capacity of $840\ Ah$, as can be seen on the datasheet in the c appendix.

The two step-down DC-DC converters are used to decrease the input voltage, $48V$, to feed the circuit equipment: the step-down DC-DC converter $48V$-$36V$ to charge the bike's batteries and the stepdown DC-DC converter $48V$-$12V$ to feed display and lights of the system.

All the components of the circuit are summarized in Table 2.

Solar Panels	8 x LUXPOWER SERIES 4, 365 W Mono
Battery	3 x eBick Ultra 175, 48V_280Ah
MPPT Converter	Victron BlueSolar 150/85
Controller	Raspberry Pi
StepDown DC-DC Converter 48V-36V	DTK-2MHLPF Series
StepDown DC-DC Converter 48V-12V	DTK-2MHLPF Series

Table 2: Elements of the circuit

15.8 Software simulation systems

Once the off-grid system has been fully designed, further situations must be explored, such as a grid-connected system that eliminates the cost of batteries or a hybrid system that retains the batteries. Both are prepared to use grid energy as needed during the winter months and sell excess energy during the summer months.

One of the biggest challenges in using a model software like HOMER is selecting the correct parameters and data.

15.8.1 Use of Data

The load data profile of the ECS is based on the use made of the rental e-bikes throughout the year in the Barcelona municipality.

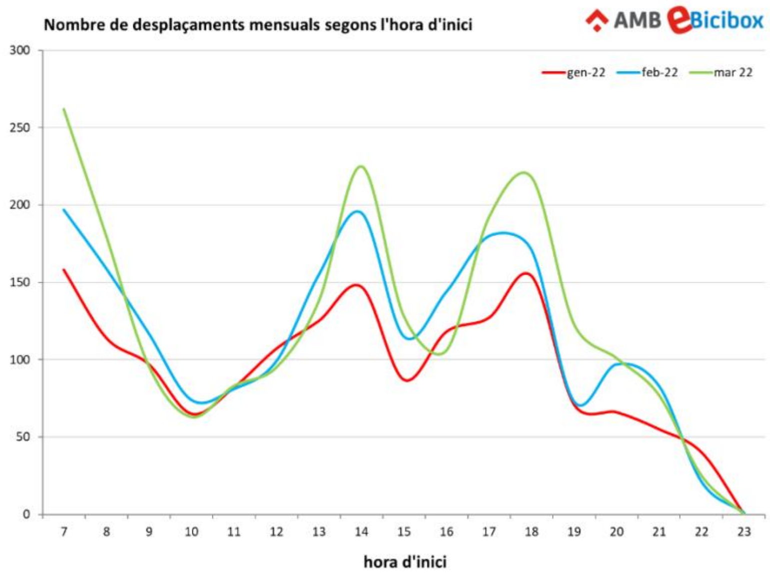
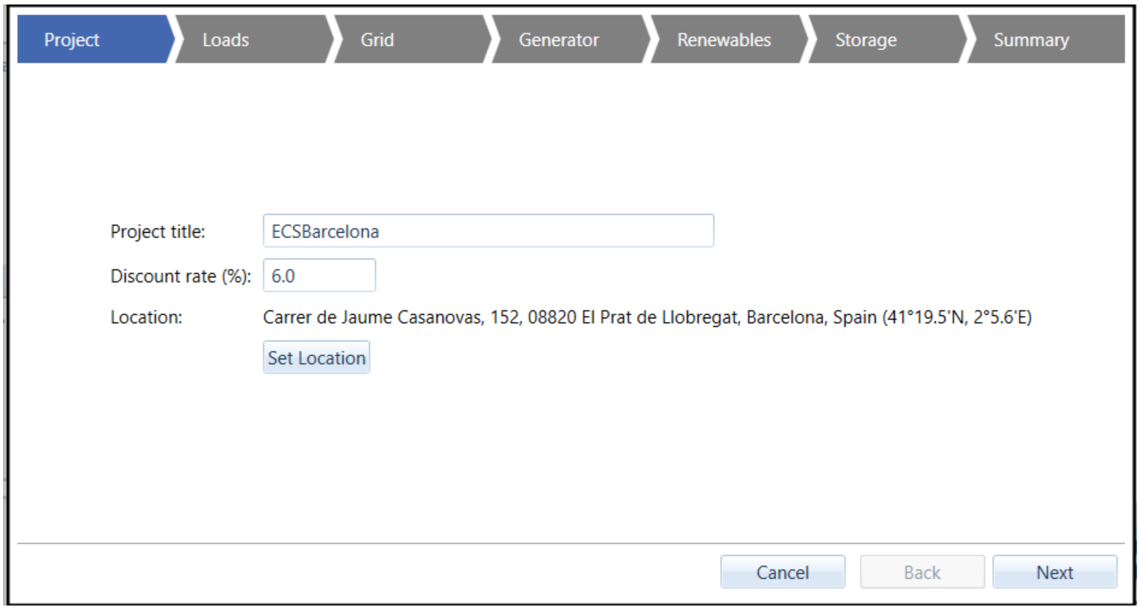
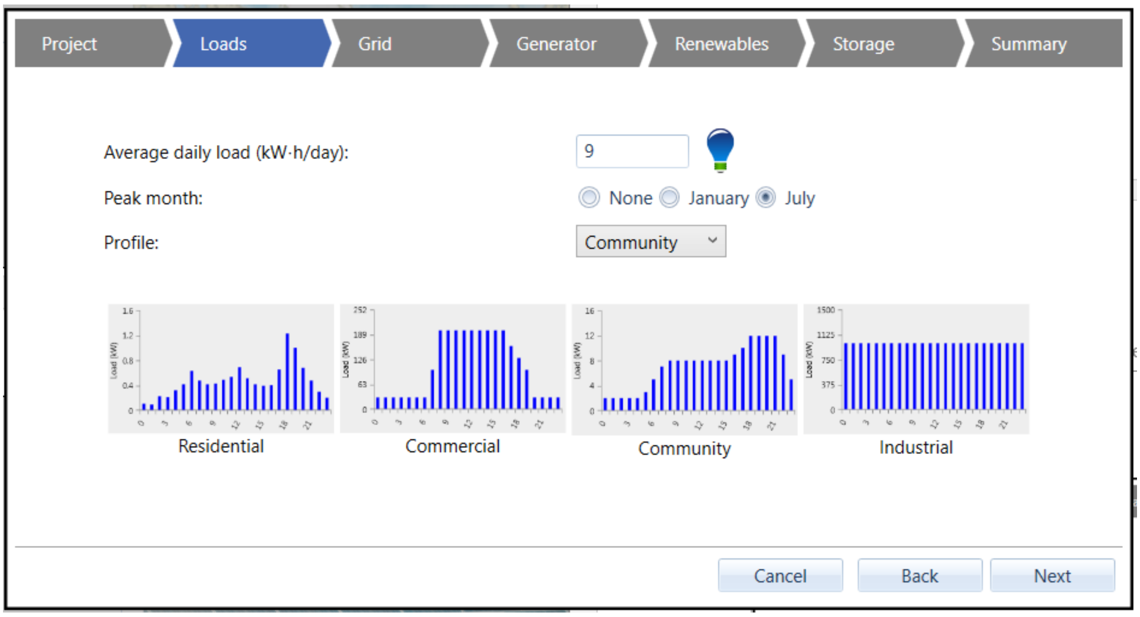


Figure 21: Number of journeys per month by start time

To convert this information into an energy load, it has been believed that once the various usage curves decline, there will be a higher demand for energy as the journey concludes, hence the load must be higher (the user parks the bike, and its battery has been discharged). This suggests that the peak energy consumption will be attained at eleven o'clock.

The actual fleet of e-bikes is 300, which means 30 ESC in the municipality.





We select community profile type for default because we assume that our peak of consumption during the day will be higher when drivers finish commuting home. And because we are in the northern hemisphere our peak month will be July.

For the connected, to the grid-scenario, the power price depends on the company that supplies the electricity to the system. The selected company is SOMS ENERGIA a local company that only produces and sells green energy. The cost of electricity fluctuates depending on the season and the month as is shown in Figure 22, to transfer this information into the program to introduce the energy purchase prices, an estimate of the price for each month based on the hours in which the energy will be consumed was made.

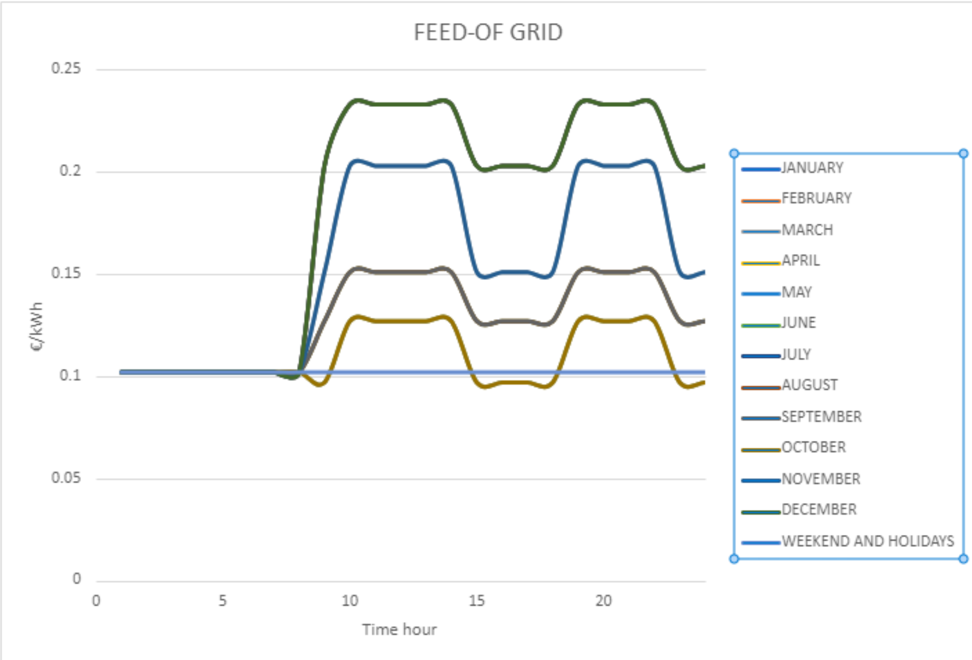


Figure 22: Feed-of grid

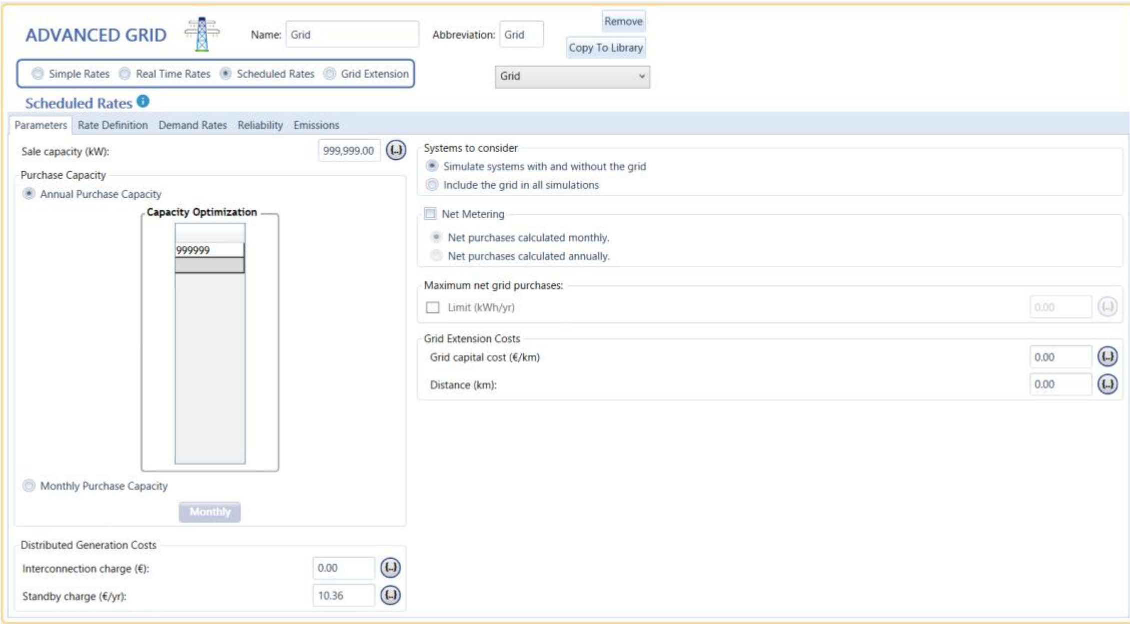


Figure 23: Grid simulation

The software allows users to create a solar panel and a base battery and then alter the parameters based on the figures above. All data calculated on the off-grid system, including system losses, were incorporated as parameters in the simulation.

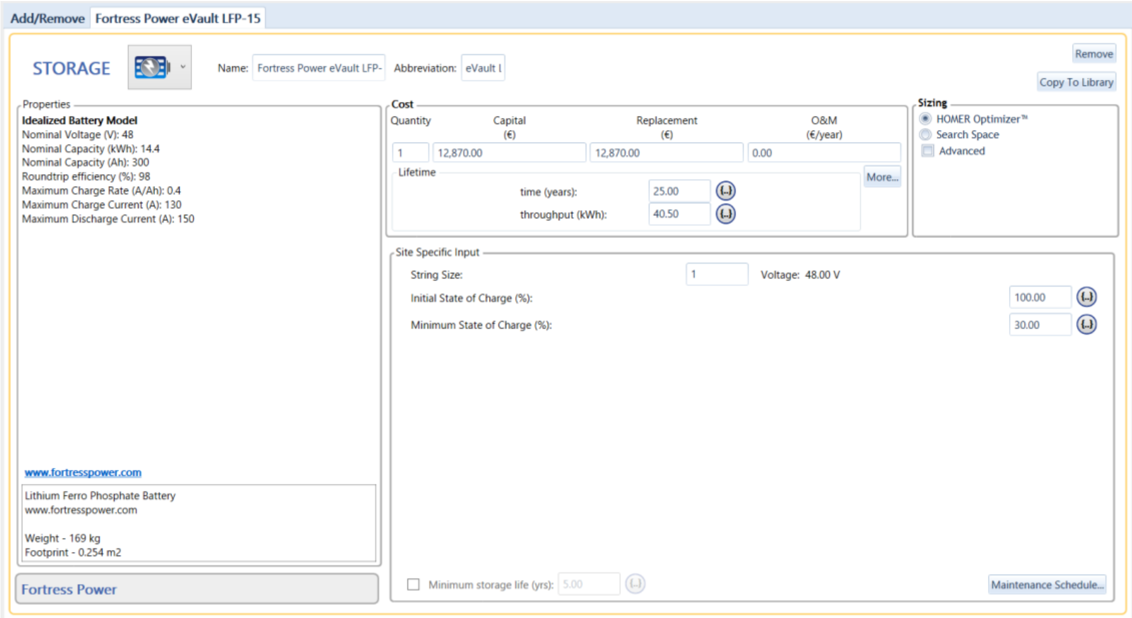


Figure 24: Storage simulation

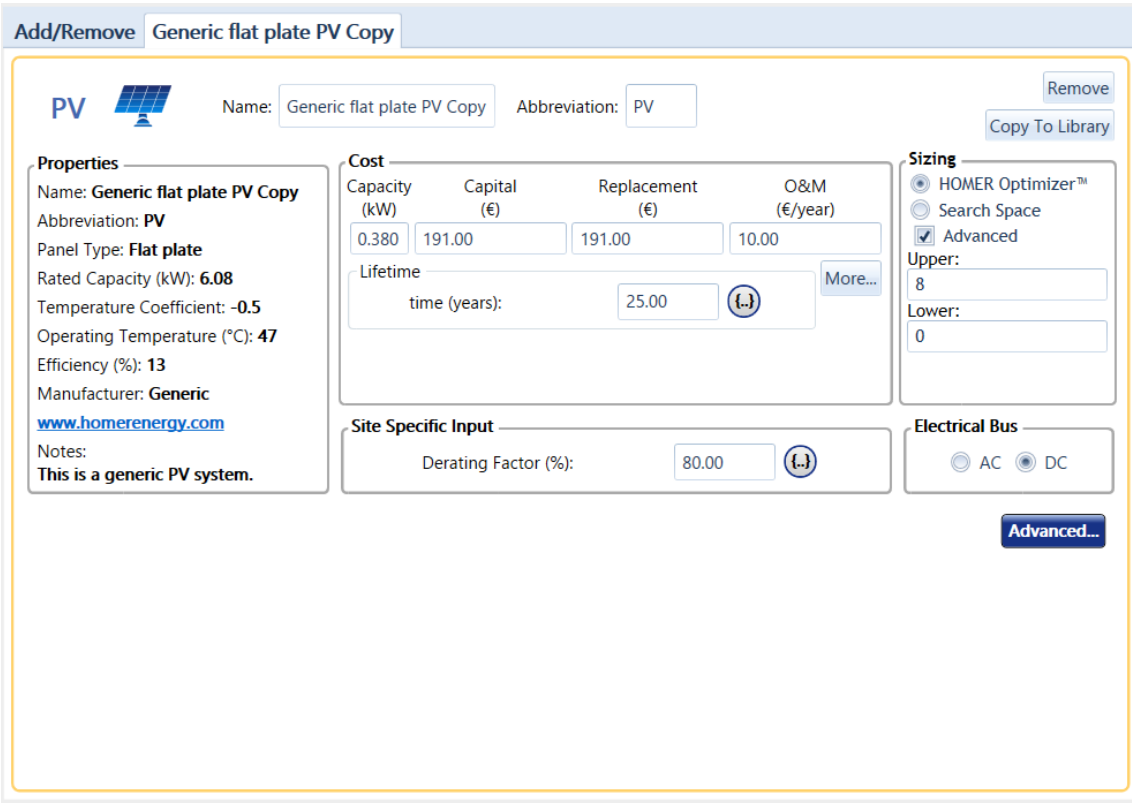


Figure 25: Solar Panel simulation

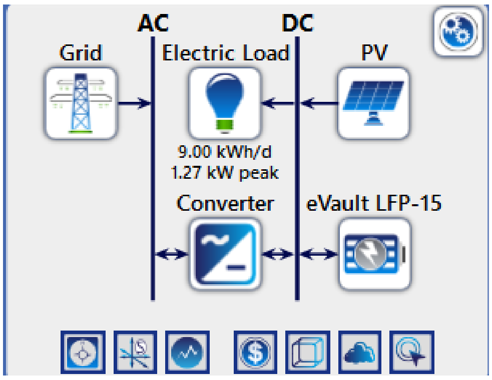


Figure 26: PV diagram

15.9 Mechanical design and calculation

The solar panel of the existing charging station built in most cities center is commonly installed on the surface of any roof structure and has a fixed elevation. The roof is often designed with a duo-pitch shape with double beam support underneath or sometimes single. The number of bikes and the requirement for the solar panel are lower due to less energy consumption. Hence the structure is sufficient. Besides, these stations are also connected to the grid and are not self-sustainable. The calculation carried out in this section are estimated for the worst-case scenario that could happen. The design proposed in this section is a mono-pitch roof with four beams for support.

Referring to the chapter above, the designed roof was a mono-pitch with said elevation angle from the horizontal surface. Since the station was designed to be built in Barcelona, the azimuth value of 0° towards the south has been chosen due to the position situated in the northern hemisphere region of the Earth. Other range values of tilt angle and azimuth would lead to a reduction in solar panel efficiency and losses of energy yield (González-González, et al., 2022).

<u>Structure dimension and parameters</u>

This chapter explains the necessary steps realized to determine the load that acts upon the structure of the solar charging station. To ensure a structurally sound and stable design, the calculation and analysis of load, shear stress, and axial force throughout the different members of the frame joint need to be considered. The direction of the load or force that acted upon the surface of the building either directly or with a certain value of angle played an important role in finding the total summation of force.

The selected model of solar panel has a length of 175.6 cm and a width of 103.9 cm according to b. Then, the total length of the solar panel connected in parallel in portrait form resulted in a value of 831.2 cm (refers to m). The width of the roof structure depends on the designated height of the back beam which was the highest of all. As the planned structure had an enclosed wall around its perimeter, so the appropriate base width allocated was 300 cm considering the average length of an electric bike is 180 cm and has sufficient space to drive back towards the exit. Afterward, the designed base length of the station was 1040 cm due to the total length of 10 bikes occupying almost 840 cm. Then, an extra space of 200 cm was reserved for the installation of a battery and other electrical components such as the MPPT controller.

The width of the mono-pitch roof can be found by simple Pythagoras calculation and has a value of 380.7 cm (refers to m). The total roof area of the structure obtained was 39. 59 m^2, almost 40 m^2 according to k. On the other hand, the base area obtained was 31.2 m^2 (refers to calculation n).

The roof structure was supported by 4 ISO square hollow type beams underneath it and the load will assumedly be distributed equally between those beams. These front and back beams did not have the same height due to the slight elevation. The designated height for the front shorter beam was designated to have 200 cm meanwhile the height of the back beam obtained was 434.4 cm (o).

The slightest increase of height for the back beam would also allow the solar module to ventilate during the hotter high temperature during the summer, particularly in a location like Barcelona. Thus, allowing a high quantity of air circulation beneath the solar module. Moreover, the optimal designated height for both front and back beams would prevent any cause of obstruction for the user underneath which could cause a serious accident.

15.9.1 Load determination and calculation

There is a different type of loads that can contribute to the overall value of the force or pressure, which is live load, dead load, variable load, snow, wind, and seismic actions. There was also a different method to follow to obtain the corresponding value. The dead load is the weight of static material of the construction such as the weight of the solar module itself, the mounting rail, and the connecting trusses between edge beams and the slanted roof. The weight of roofing covering material, the water-resistant laminate coating, and the clamps can be neglected because of their light mass.

The total value of the dead load obtained is 24 kN (refer to calculation in p).

Next, the live load is the weight of a moving organism or object that change over time such as the weight of a person that climbs on top of the roof for initial installation and maintenance purpose. The solar module cannot be reached by using a simple ladder because of the tall height and the usage of an elevating platform like a scissor lift is required. The mass of two people equipped with heavy equipment bags was considered during the calculation so that they can undergo the mounting of solar panels safely without the possibility of falling through.

Wind load:

First and foremost, the value of the basic wind velocity (V_b) for our exact location of the structure needed to be known. The calculation is carried out referring to the (Technical Committee CEN/TC250 nStructural Eurocode", 2005) guide document. This value can be found in the equation below:

$$\text{Basic wind velocity } (V_b) = C_{dir} \text{ x } C_{season} \text{ x } V_{bo};$$

V_{bo} is the fundamental value of the basic wind velocity, and its value can be obtained from Figure 27: Basic velocity of the wind throughout the Iberian PeninsulaFigure 27 below which is situated in Zone C (29 m/s).

C_{dir} is the directional factor and can be considered as 1.0 according to guide unless for a specific reason.

C_{season} is the seasonal factor and can be considered as 1.0 according to guide unless for a specific reason.

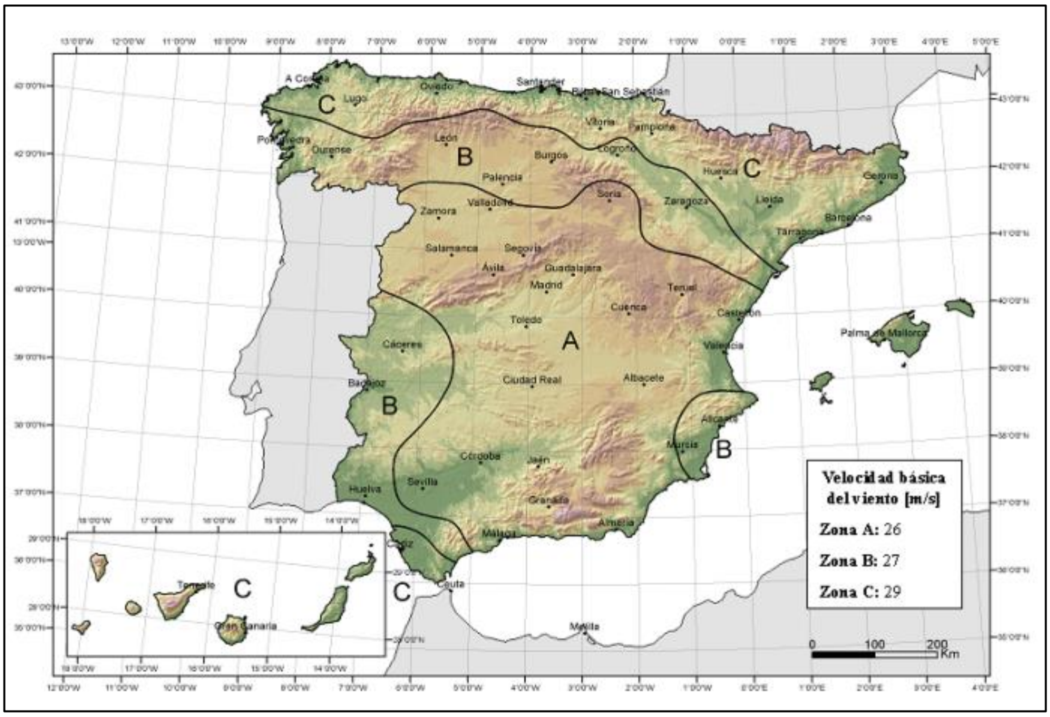


Figure 27: Basic velocity of the wind throughout the Iberian Peninsula

(Bordanaba, 2022)

Hence, the obtained value for basic wind velocity is 29 m/s (appendix q). This value will be needed for the next calculation.

Afterward, the value of wind peak velocity pressure, q_p (z_e) was required. This value represented the total force exerted upon a structure by the wind at the given height, which includes mean and short-term velocity fluctuations. The value can be obtained through a series of formulas, but the simplest and quickest version would be to insert the required variable in the Eurocode website as shown in Figure 28 below.

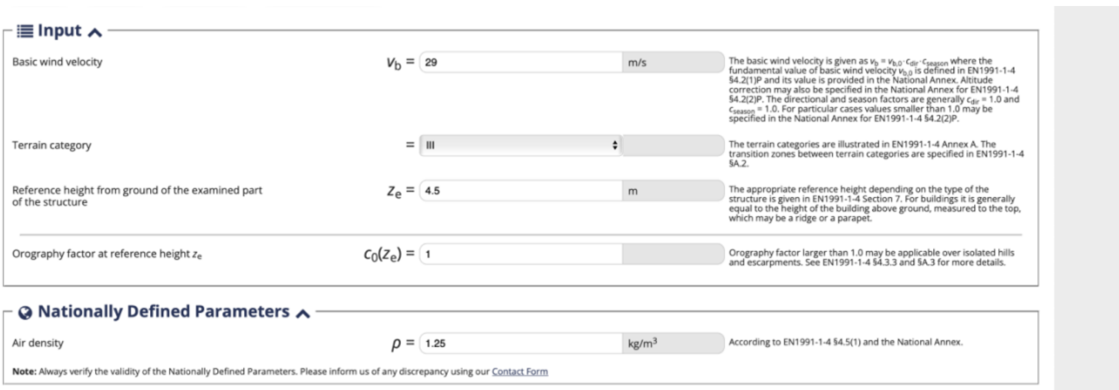


Figure 28: Input value for wind peak velocity pressure

(EurocodeAppliedTeam, s.d.)

The terrain category chosen is type 3 according to the guide since our solar charging station will be situated in an area suburban area where there is regular vegetation or building with a separation maximum of 20 isolated obstacle height´s.

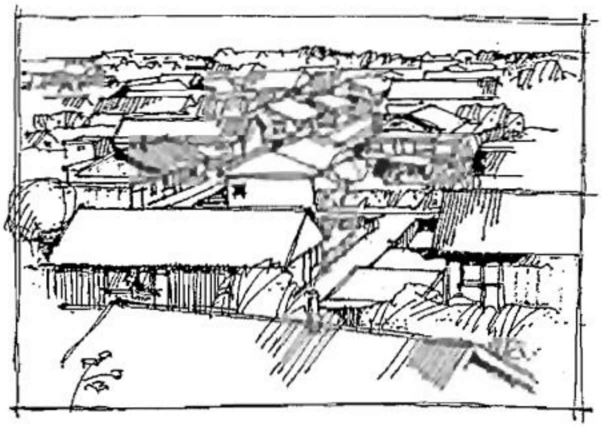


Figure 29: Illustration and category of terrain

The value for z_e determined was the height of the back beam from the ground of the structure which is the tallest than the lower front and has an approximate value of 5 m.
The orography factor at the reference height, $c_o(z_e)$ was 1 because the structure will not be built over isolated hills or cliffs, but instead on a plain surface terrain without any elevation or slope. The effect of increased wind velocities and changing of its direction near neighbouring buildings due to be the terrain effect category will be neglected. In addition, the potential shading effect would cause our solar panel to reduce the maximum potential efficiency. The fixed value of the normal air density selected is 1.25 kg/m^3. The calculated value of wind peak velocity pressure q_p (z_e) obtained was 673 N/m^2.
The calculated value was the general uniform force that acted toward all the surfaces of the structure when the velocity of air is at the maximum without considering the actual wind pressure and its force coefficient. Moreover, the possible combination of positive (push) and negative (suction) wind load on a different surface, frame member, another possible opening, and leakage path during the worst scenario are also neglected from the analysis even though it will be varied on different places and season throughout the year. This is because the detailed analysis and calculation will be less related to the mechanical engineering field.

Snow load:

The value of the force acted upon by the snow weight can be determined from the following equation according to the (Technical Committee CENITC250 "Structural Eurocodes", 2003) guidelines:

Snow action, s: μ_1 x C_e x C_t x S_k;

μ_1 is the snow load shape coefficient used for mono-pitch roofs can be obtained from the equation below:

$30^o < \alpha < 60^o$

$\mu_1 = 0.8(60 - \alpha)/30$

α represented the elevation angle from the horizontal surface as shown in the figure below and can be found in the chapter above. Hence, the calculated value of μ_1 is 0.5867 (r).

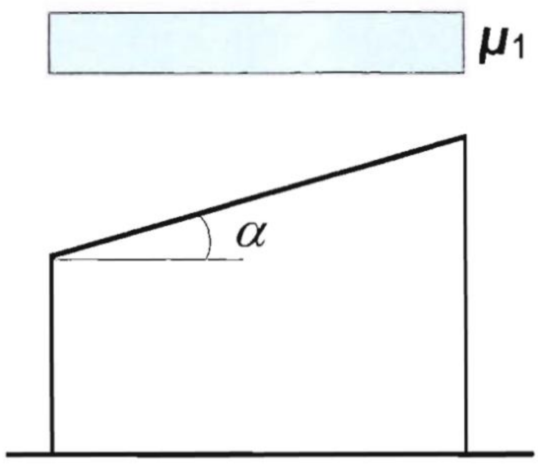


Figure 30: Snow load shape coefficient – mono-pitch roof

(Technical Committee CENITC250 "Structural Eurocodes", 2003)

C_e is the exposure coefficient and should be taken as 1.0 according to the recommended values of the guide unless otherwise specified for different topographies. The structure will be built on a normal topography area.
C_t is the thermal coefficient and should be taken as 1.0 which is the reduction of snow loads on roofs with high thermal transmittance (>1 W/m^{2}K)

S_k is the characteristic of snow on the ground at the relevant and can be found in the following equation:

$$S_k = (0.190Z - 0.095)\left[1 + \left(\frac{A}{524}\right)^2\right];$$

Z is the zone number given on the map
A is the site altitude above sea level (m)

The altitude value can be found in Figure 31 below which is 12 m.

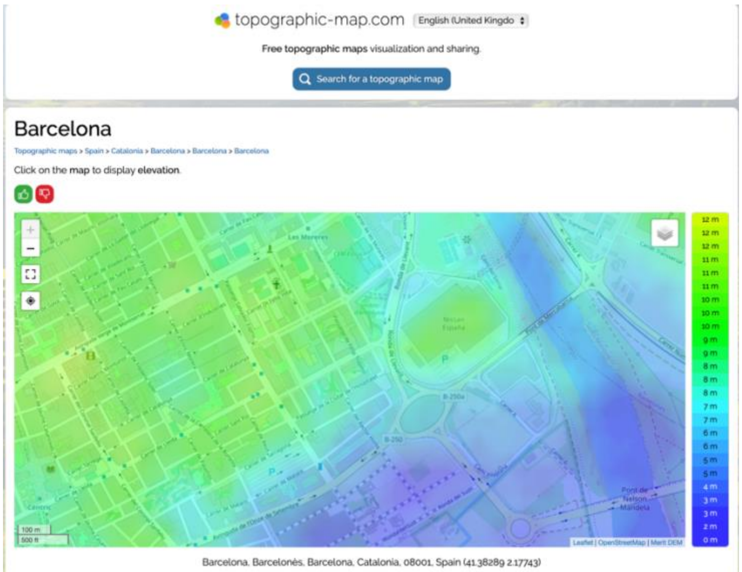


Figure 31: Topographic map of Barcelona

(maps, s.d.)

On the other hand, the zone number can be shown in the figure below that coincide with the exact location of the structure, which is in zone 4.

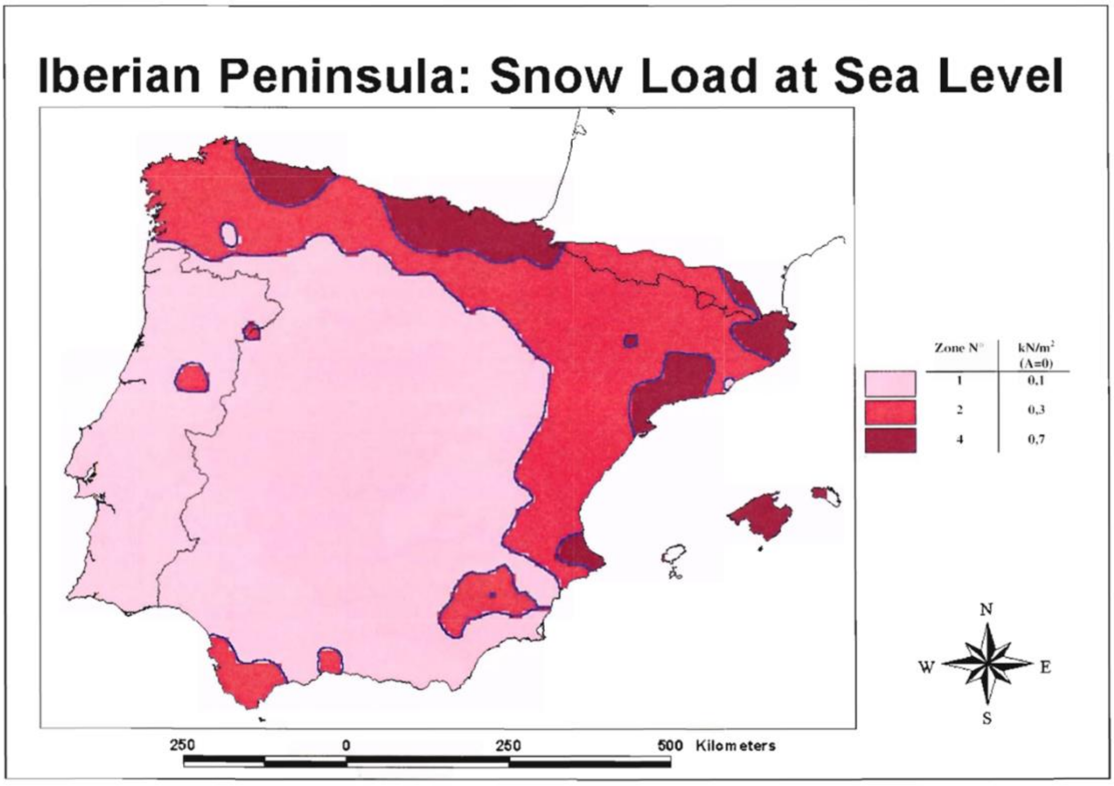


Figure 32:European Ground Snow Load Maps

(Technical Committee CENITC250 "Structural Eurocodes", 2003)

Thus, the calculated value for S_k is 0.6653 kN/m^2 (s). After completely obtaining the value of the variable, we can proceed with the final calculation of the snow load which was 0.3904 kN/m^2 (refers to t). Also, the force resulting from the seismic action was not taken into consideration in this project.

<u>Calculation and selecting of beam</u>

The vertical force that acted upon the surface of the roof was the total summation of the dead load, snow, and wind load calculated in the section before (refers to p). Meanwhile, the horizontal component of a force that acts upon the beam will only be the wind force. The vertical force that acts on the designed beam was 6 kN.

The horizontal force value acted on the exterior surface of the beam in any direction with angle of 90^o

It was considered to act in a form of direction on 1 m of horizontal longitude, thus obtaining the value of 0.673 kN/m (refers to u).

The calculation of internal force that acted upon all the structure frame was carried out in this chapter. Afterwards, with the calculated value of force both vertical and horizontal, the least favorable cross-sectional area of the beams can be determined. The first step was dimensioning and sketching the actual beam in Wineva software. By substituting the required value in the software with the already calculated value of forces before. The structured was chosen as isostatic and the type of link between the ground and the beam was embedment.

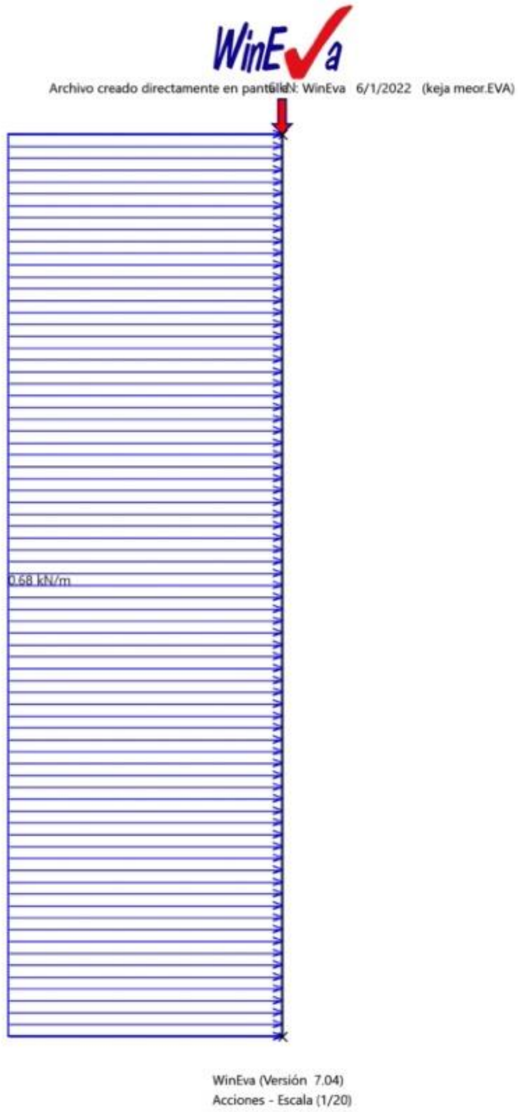


Figure 33:Sketching the element value

With the simulation from the software, the value of axial force, shear stress and bending moment can be determined. The next step was determining the least favorable cross sectional or point of node with higher value of axial force and bending moment. Then, substituting the value in the following equation:

$$\sigma = \frac{Nx}{A} + \frac{Mz}{Iz}(y)$$

σ is the normal stress or tension (kg/cm^2)

A is the cross-sectional area (cm^2)

Nx is the axial force (N)

Mz is the bending moment (Ncm)
Iz is the inertia moment of section (cm^4)
Y is the length from the center to the end of least favorable part (cm)

Since that the properties of beam chosen was considered to have thick wall according to equation below and referring the calculation of w.

e > 0.1 * the smallest dimension of beam $\rightarrow$ thick wall profile
e < 0.1 * the smallest dimension of beam $\rightarrow$ thin wall profile

The value of normal stress obtained can then be substituted into the following equation to find the equivalent stress of Von Mises.

$$\sigma_{eq\ Von\ Mises} = \sqrt{\sigma^2 + 3\tau^2}$$

$\sigma_{eq\ Von\ Mises}$ is the equivalent value of stress according to the criteria of theory of maximum energy distortion of Von Mises
τ is the shear stress or tangent tension

The distribution of tangent stress on the cross-sectional area of the beam was 0 due that point of the section that have the most force acted upon was not from the center of beam. Therefore, the calculated value of stress was the same for the equivalent stress of Von Mises. The value of area and the inertia moment of section can be obtained from the beam sheet datasheet. The value of equivalent stress needed to be less and not exceeded than the maximum yield limit of steel which is 2600 kg/cm^2. This limit value divided by security factor of 1.5 considering that the seismic actions, temperature stress and other possible fluctuations of force were not calculated in detail. The corresponding sign convention of the force also needed to consider. The value for the Von Mises equivalent stress is 1733.33 kg/cm^2. After the obtaining the suitable length and thickness of the beam, the design can be sketched in 2D and modelized in 3D in Autocad.

16 Results/findings and Discussion

The *E-bike charging station* is an off-grid self-sufficient charging station for E-bikes. It is equipped with 8 “LUXPOWER SERIES 4 360-380W Mono” connected in parallel with an output voltage of $48V$. The electricity produced by the photovoltaic modules flows into the circuit reaching the “BluSolar Charge controller MPPT”, the maximum power point tracking, which maximizes the power produced favoring more efficient recharging of the battery. No step-down C-DC converter is required because the battery and the PV’s array work at the same nominal voltage, so charging can start instantly.

The battery compartment is composed of 3 “EBICK ULTRA 175” batteries connected in parallel with a capacity of 840 Ah and it can provide autonomy of 2 days and 15 hours without sun. To feed the different loads is necessary to introduce step-down DC-DC current “DTK-2MHLPF Series” to feed the lights and the display, as well as the batteries of the bike; all the loads that work with direct current.

In one year, the PV system produces 4301,54 $\frac{kWh}{year}$, enough to power the batteries of 10 e-bikes two times per day, lights and displays that consume an overall 3285 $\frac{kWh}{year}$.

16.1.1 Achieved results

After optimizing the system, HOMMER states that the most advantageous approach is a grid-connected system, which saves on battery costs. However, because it would be a public system, it is unknown how much it would cost to link the system to the grid.

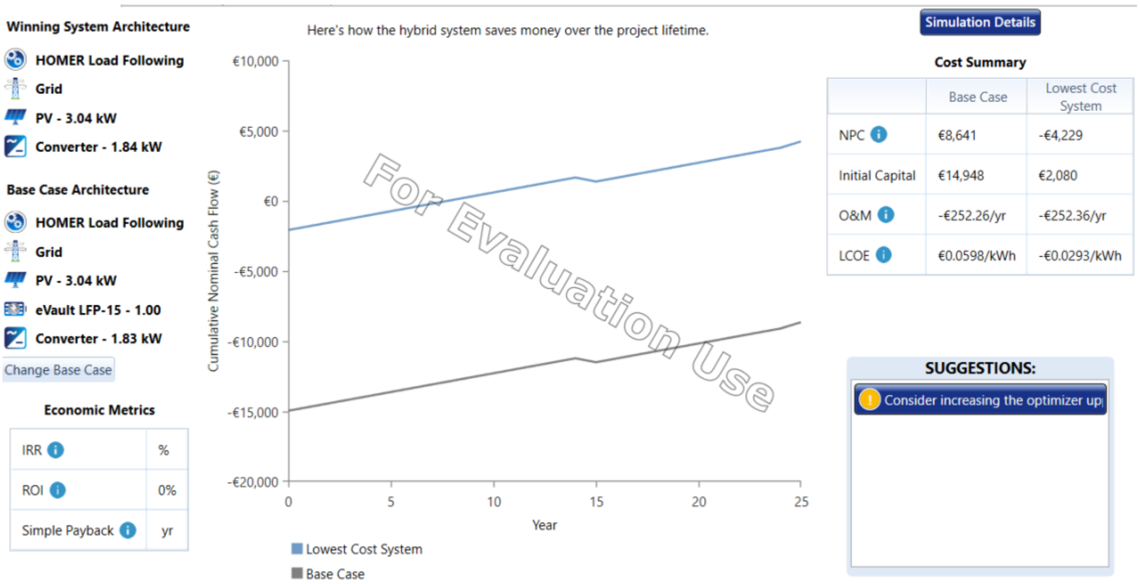
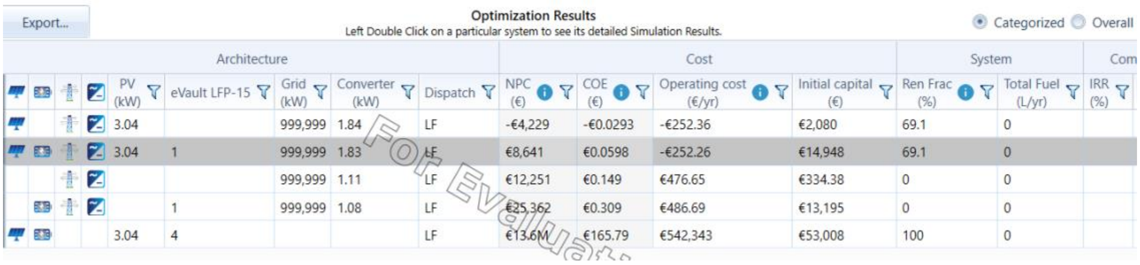


Figure 34:HOMMER results



Optimization Results

Left Double Click on a particular system to see its detailed Simulation Results.

PV (kW)	eVault LFP-15	Grid (kW)	Converter (kW)	Dispatch	NPC (€)	COE (€)	Operating cost (€/yr)	Initial capital (€)	Ren Frac (%)	Total Fuel (L/yr)	IRR (%)
3.04		999,999	1.84	LF	-€4,229	-€0.0293	-€252.36	€2,080	69.1	0	
3.04	1	999,999	1.83	LF	€8,641	€0.0598	-€252.26	€14,948	69.1	0	
		999,999	1.11	LF	€12,251	€0.149	€476.65	€334.38	0	0	
	1	999,999	1.08	LF	€25,362	€0.309	€486.69	€13,195	0	0	
3.04	4			LF	€13.6M	€165.79	€542,343	€53,008	100	0	

Figure 35:HOMMER economic comparison

Wineva demonstrated in the Figure 36, the value of the axial force which is 6kN and the negative sign convention which represented compression on the pillars.

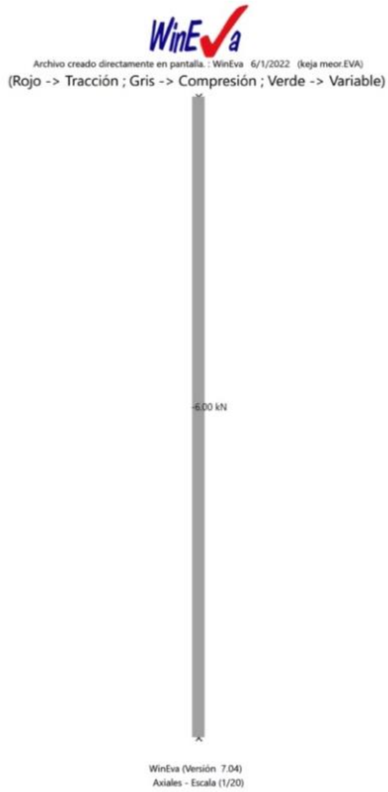


Figure 36: The axial force result

Afterwards, the value of shear stress can be shown with the software in Figure 37, where when the length is at minimum, the value was greater whereas for the opposite, it was almost to 0kN.

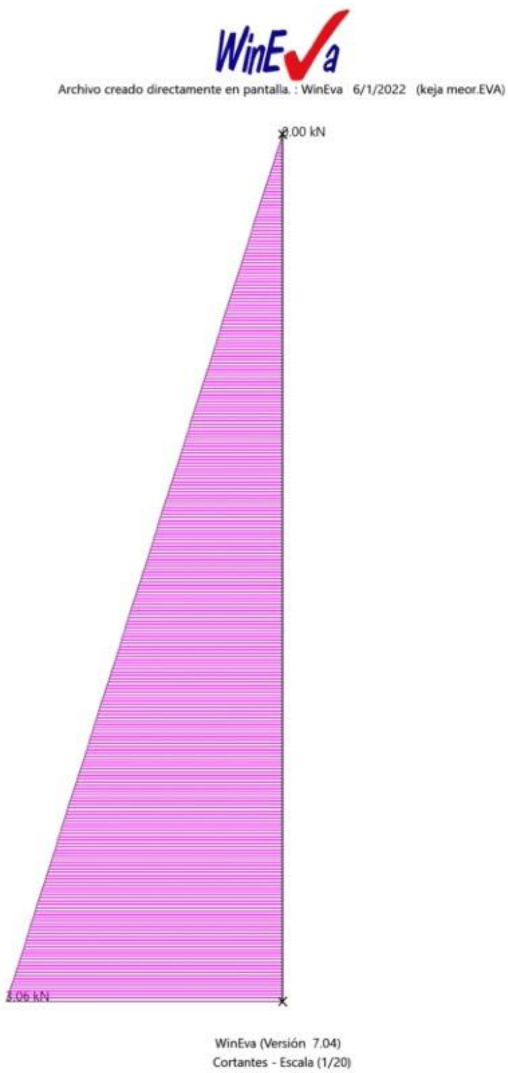


Figure 37: The shear stress analysis

Later, the value of the bending moment can be obtained where the force was higher at the initial length of the beam as can be shown in Figure 38.

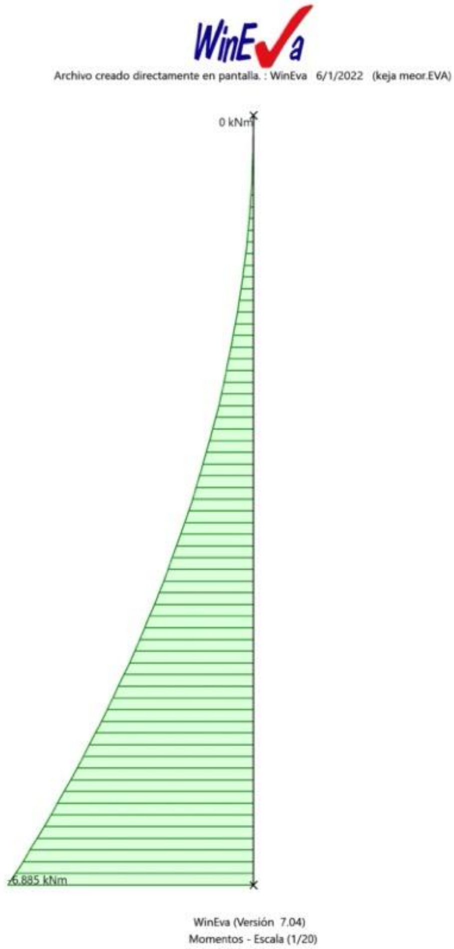


Figure 38:The bending moment analysis

By choosing the appropriate beam in the datasheet, the normal stress obtained from the calculation in appendix v is 1102.6 kg/cm^2. The calculated value of Von Mises equivalent stress does not exceed the yield strength limit (refers to x). Hence, the selected beam from the datasheet is ISO Steel 90mm x 90mm width thickness hollow of 8.0mm has been highlighted in appendix g.

The 3D design of the structure is realized in the Inventor with the planned dimension from the section before and the design had an exact scale with the actual design.

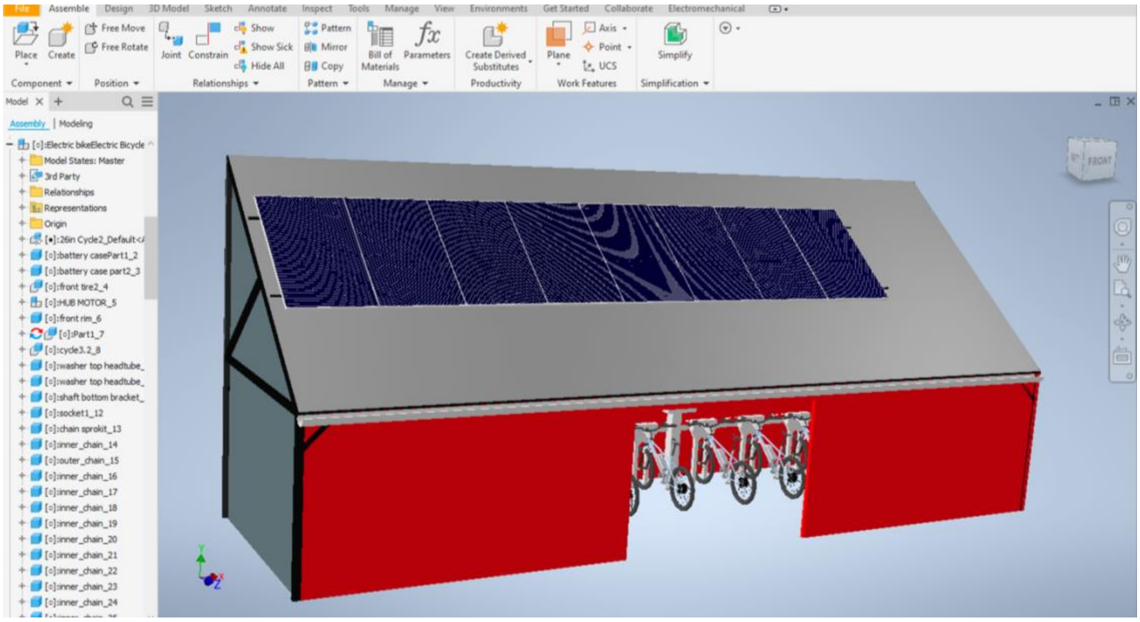


Figure 39:The complete design in Inventor

The Figure 40 below shows the design of the structure frame without the walls and the exact number of 10 electric bikes that fitted in the station.

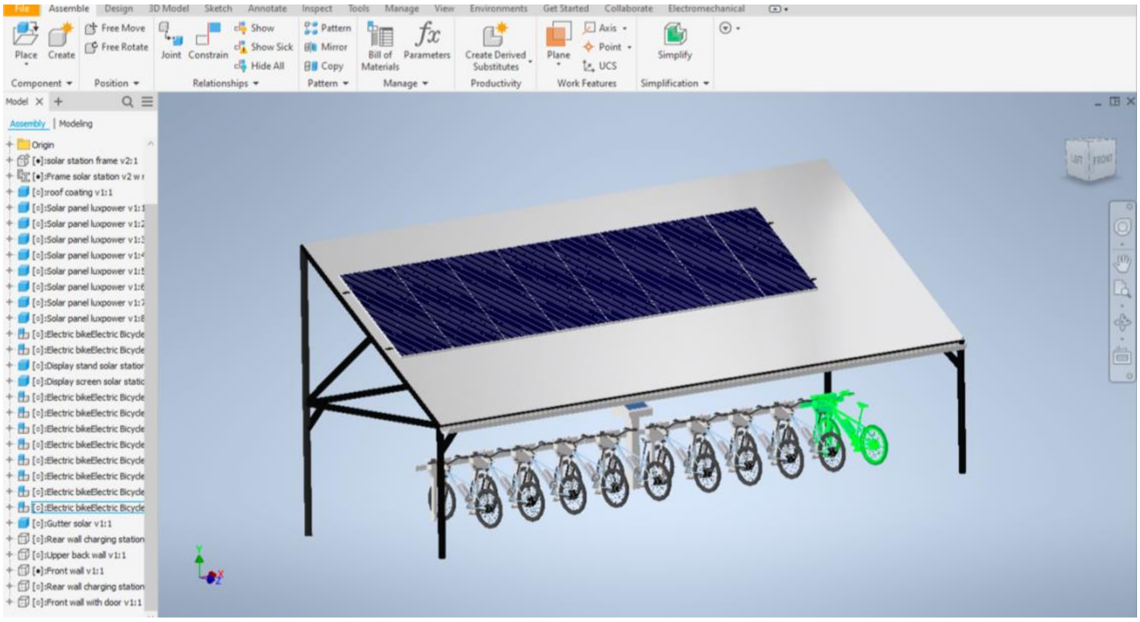


Figure 40:The frame design in Inventor

The 3D model of the bike was downloaded from available model in Grabcad. Figure 41 show the position of the stand with the bike, position of the charger plugs head, corresponding red and blue signal light and the gripper position. (Narkar, 2021)

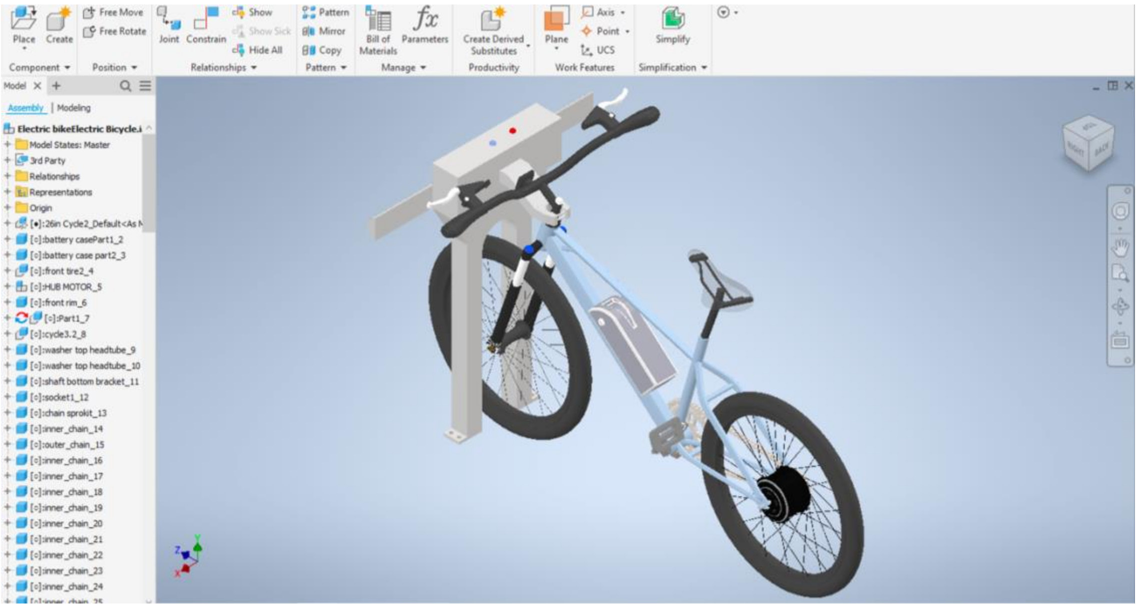


Figure 41:The E-bike charging dock

The design of the charging dock that would store and fits the width of the electric bike safely without the obstruction from the others. It would also help it stand straight without falling.

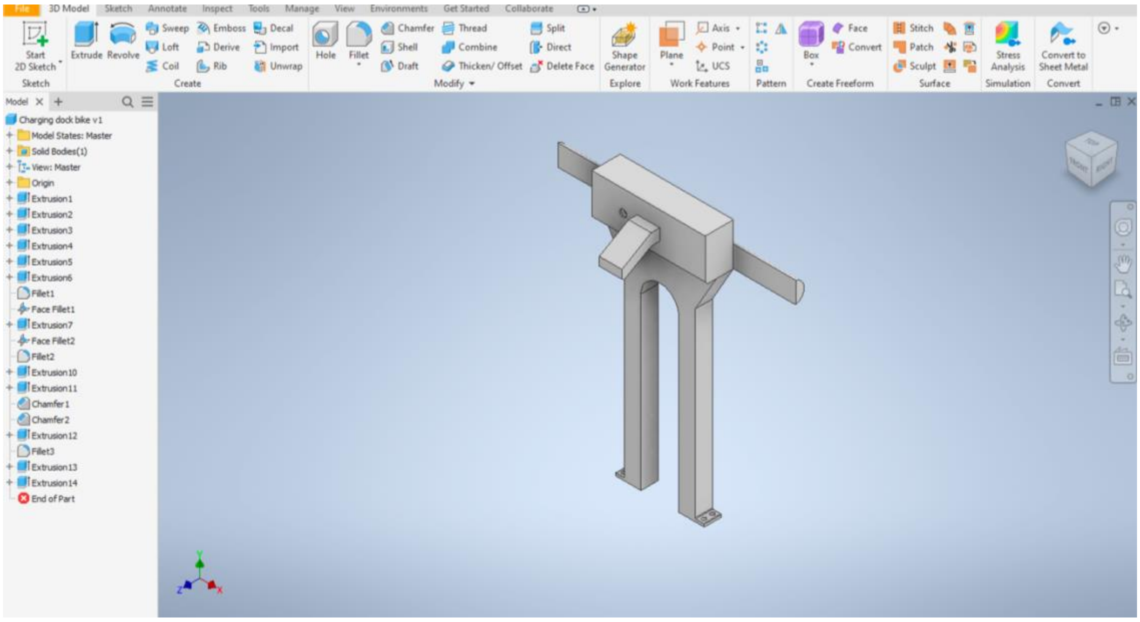


Figure 42:The 3D charging dock design

The gripper system made of high strength steel that would lock the bike frame to would also keep the bike still vertically. In addition, it had an automatic lock system that would open when receive the signal from the center.

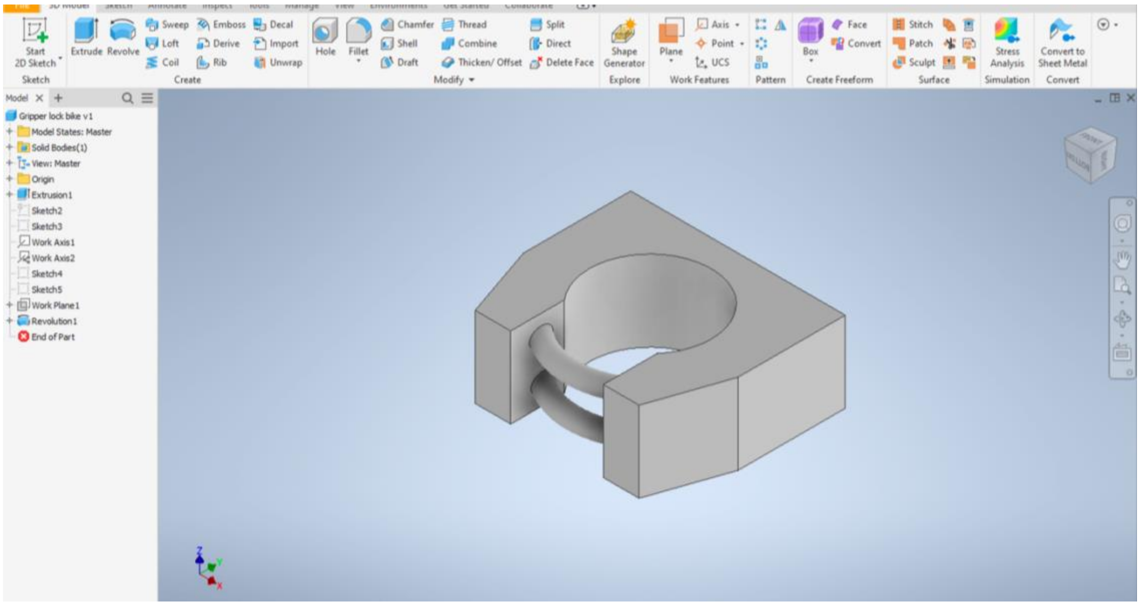


Figure 43: The lock mechanism for E-bike frame

The display stand or also the center command that store the electronic circuit and enable the lock and unlock of each bike separately. Also, monitor the amount of bike available or lighting the correspondent light or green bulb.

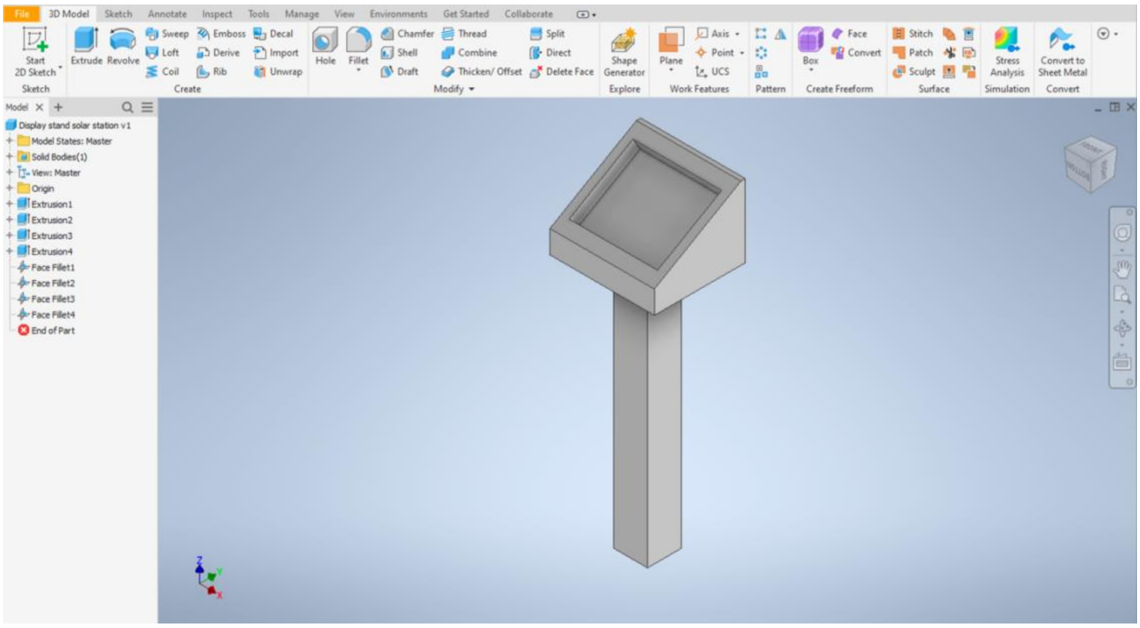


Figure 44:The main display and controller stand

17 Conclusions

Looking back at the business part, it can be concluded, that creation of a business in particular, Solhavn is not without great challenges that it has to overcome but with the right business plan it is able to become a successful company. The first and most oppressive hurdle consists of the initial start-up costs that is required to give life to the company. This dilemma can be remedied by outreaching to the community and expanding the horizons of the company's network in the form of crowdfunding and periodic rounds of subsidies. There are still residual barriers SolHavn must confront as new players in the industry, introducing a relatively new and innovative product. Largely in part to SolHavn's commitment to sustainability and the subsequent values that serve to better the planet, the future of the company is expected to experience perpetual growth for the upcoming years as social awareness begins to increase and align itself with sustainable mindset.

After all the calculations that have been performed and the production of energy that has obtained from the off-grid system, it can be assured that the buyer will receive a system that is completely independent of the electrical grid. The system of batteries that are utilized are in fact a viable, economic solution largely in part to their long-life cycle and ability to fulfill the stringent energy demands. Due to the installation cite being in close proximity and easy access to the electrical grid, and the principal buyer being the municipality of Barcelona, the transaction should run seamlessly. After conducting the calculations through the computer programs the charging station would be able to discard the batteries at an economic rate. The data given by the software are approximate, but in the case that the system selected does not suit the customers' needs, it would be augmented to fulfill specific needs.

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19 Appendices

A. Income statement for the pessimistic scenario

Scenario:										
1	Year_1	Year_2	Year_3	Year_4	Year_5	Year_6	Year_7	Year_8	Year_9	Year_10
Units sold	13	25	50	100	175	250	480	720	1020	1260
Income statement:										
Euro	Year_1	Year_2	Year_3	Year_4	Year_5	Year_6	Year_7	Year_8	Year_9	Year_10
Revenue	311.987,00 €	599.975,00 €	1.199.950,00 €	2.399.900,00 €	4.199.825,00 €	5.999.750,00 €	11.519.520,00 €	17.279.280,00 €	24.478.980,00 €	30.238.740,00 €
Materials	210.205,84 €	404.242,00 €	808.484,00 €	1.616.968,00 €	2.829.694,00 €	4.042.420,00 €	7.761.446,40 €	11.642.169,60 €	16.493.073,60 €	20.373.796,80 €
Labour	64.610,00 €	124.250,00 €	248.500,00 €	497.000,00 €	869.750,00 €	1.242.500,00 €	2.385.600,00 €	3.578.400,00 €	5.069.400,00 €	6.262.200,00 €
Variable Cost	274.815,84 €	528.492,00 €	1.056.984,00 €	2.113.968,00 €	3.699.444,00 €	5.284.920,00 €	10.147.046,40 €	15.220.569,60 €	21.562.473,60 €	26.635.996,80 €
Contribution Margin	**37.171,16 €**	**71.483,00 €**	**142.966,00 €**	**285.932,00 €**	**500.381,00 €**	**714.830,00 €**	**1.372.473,60 €**	**2.058.710,40 €**	**2.916.506,40 €**	**3.602.743,20 €**
Margin %		*11,9%*	*11,9%*	*11,9%*	*11,9%*	*11,9%*	*11,9%*	*11,9%*	*11,9%*	*11,9%*
Marketing plan expenses	€ 2.925,00	€ 5.625,00	€ 11.250,00	€ 22.500,00	€ 39.375,00	€ 56.250,00	€ 108.000,00	€ 162.000,00	€ 229.500,00	€ 283.500,00
EBITDA	€ 34.246,16	€ 65.858,00	€ 131.716,00	€ 263.432,00	€ 461.006,00	€ 658.580,00	€ 1.264.473,60	€ 1.896.710,40	€ 2.687.006,40	€ 3.319.243,20
Depreciation	€ 1.529,73	€ 1.529,73	€ 1.529,73	€ 1.529,73	€ 1.529,73	€ 1.528,88	€ 1.528,88	€ 1.528,88	€ 1.528,88	€ 1.528,88
EBIT	€ 32.716,43	€ 64.328,27	€ 130.186,27	€ 261.902,27	€ 459.476,27	€ 657.051,12	€ 1.262.944,72	€ 1.895.181,52	€ 2.685.477,52	€ 3.317.714,32
Profit	**€ 25.518,82**	**€ 50.176,05**	**€ 101.545,29**	**€ 204.283,77**	**€ 358.391,49**	**€ 512.499,87**	**€ 985.096,88**	**€ 1.478.241,58**	**€ 2.094.672,46**	**€ 2.587.817,17**

B. Income statement for the optimistic scenario

Scenario:										
3	Year_1	Year_2	Year_3	Year_4	Year_5	Year_6	Year_7	Year_8	Year_9	Year_10
Units sold	25	50	100	200	350	500	800	1200	1700	2100
Income statement:										
Euro	Year_1	Year_2	Year_3	Year_4	Year_5	Year_6	Year_7	Year_8	Year_9	Year_10
Revenue	599.975,00 €	1.199.950,00 €	2.399.900,00 €	4.799.800,00 €	8.399.650,00 €	11.999.500,00 €	19.199.200,00 €	28.798.800,00 €	40.798.300,00 €	50.397.900,00 €
Materials	404.242,00 €	808.484,00 €	1.616.968,00 €	3.233.936,00 €	5.659.388,00 €	8.084.840,00 €	12.935.744,00 €	19.403.616,00 €	27.488.456,00 €	33.956.328,00 €
Labour	124.250,00 €	248.500,00 €	497.000,00 €	994.000,00 €	1.739.500,00 €	2.485.000,00 €	3.976.000,00 €	5.964.000,00 €	8.449.000,00 €	10.437.000,00 €
Variable Cost	528.492,00 €	1.056.984,00 €	2.113.968,00 €	4.227.936,00 €	7.398.888,00 €	10.569.840,00 €	16.911.744,00 €	25.367.616,00 €	35.937.456,00 €	44.393.328,00 €
Contribution Margin	**71.483,00 €**	**142.966,00 €**	**285.932,00 €**	**571.864,00 €**	**1.000.762,00 €**	**1.429.660,00 €**	**2.287.456,00 €**	**3.431.184,00 €**	**4.860.844,00 €**	**6.004.572,00 €**
Margin %	*11,9%*	*11,9%*	*11,9%*	*11,9%*	*11,9%*	*11,9%*	*11,9%*	*11,9%*	*11,9%*	*11,9%*
Marketing plan expenses	€ 5.625,00	€ 11.250,00	€ 22.500,00	€ 45.000,00	€ 78.750,00	€ 112.500,00	€ 180.000,00	€ 270.000,00	€ 382.500,00	€ 472.500,00
EBITDA	€ 65.858,00	€ 131.716,00	€ 263.432,00	€ 526.864,00	€ 922.012,00	€ 1.317.160,00	€ 2.107.456,00	€ 3.161.184,00	€ 4.478.344,00	€ 5.532.072,00
Depreciation	€ 1.529,73	€ 1.529,73	€ 1.529,73	€ 1.529,73	€ 1.529,73	€ 1.528,88	€ 1.528,88	€ 1.528,88	€ 1.528,88	€ 1.528,88
EBIT	€ 64.328,27	€ 130.186,27	€ 261.902,27	€ 525.334,27	€ 920.482,27	€ 1.315.631,12	€ 2.105.927,12	€ 3.159.655,12	€ 4.476.815,12	€ 5.530.543,12
Profit	**€ 50.176,05**	**€ 101.545,29**	**€ 204.283,77**	**€ 409.760,73**	**€ 717.976,17**	**€ 1.026.192,27**	**€ 1.642.623,15**	**€ 2.464.530,99**	**€ 3.491.915,79**	**€ 4.313.823,63**

C. Datasheets

a. Display SLO1555-E

Durapixel 1555-E Rugged Computer Monitor

15" TFT LCD, 1000 nits LED backlight, 1024x768

Manufacturer:

Description

Overview | Specifications

Model	DLF1555-E	DLH1555-E	SLO1555-E	SLD1555-E
Description	15" TFT LCD, 1000 nits LED backlight, 1024x768	15" TFT LCD, 1000 nits LED backlight, 1024x768	15" TFT LCD, 1000 nits LED backlight, 1024x768	15" TFT LCD, 1000 nits LED backlight, 1024x768
Screen size	15"	15"	15"	15"
Display area (mm)	304.1(H) x 228.1(V)	304.1(H) x 228.1(V)	304.1(H) x 228.1(V)	304.1(H) x 228.1(V)
Brightness	1000 cd/m²	1000 cd/m²	1000 cd/m²	1000 cd/m²
Resolution	1024x768	1024x768	1024x768	1024x768
Aspect ratio	4:03	4:03	4:03	4:03
Contrast ratio	1000:01:00	1000:01:00	1000:01:00	1000:01:00
Pixel pitch (mm)	0.297 (H) x 0.297 (V)	0.297 (H) x 0.297 (V)	0.297 (H) x 0.297 (V)	0.297 (H) x 0.297 (V)
Pixel per inch (PPI)	85	85	85	85
Viewing angle	160° (H), 140° (V)	160° (H), 140° (V)	160° (H), 140° (V)	160° (H), 140° (V)
Color saturation (NTSC)	60%	60%	60%	60%
Display colors	16.2M	16.2M	16.2M	16.2M
Response time (Typical)	16ms	16ms	16ms	16ms
Video interface	LVDS	VGA	VGA	VGA
Input power		DC 12V	DC 12V	DC 12V
Power consumption	13w	16w	16w	16w
Dimensions (mm)	326.5x253.5x11.6	326.5x253.5x11.6	389x325x60.1	389x325x61.6
Bezel size (U/B/L/R)	11.1/11.1/9.6/9.6	11.1/11.1/9.6/9.6	11.1/11.1/9.6/9.6	11.1/11.1/9.6/9.6
Weight (Net)	1.33kg	1.43kg	3.83kg	4.62kg
Mounting			VESA 75x75	VESA 75x75
OSD key		4 keys (Power switch, menu, +, -)	4 keys (Power switch, menu, +, -)	4 keys (Power switch, menu, +, -)
OSD control		Brightness, color, contrast, H/V position… etc	Brightness, color, contrast, H/V position… etc	Brightness, color, contrast, H/V position… etc
Operating temperature	-30°C ~ +80°C	-30°C ~ +80°C	-30°C ~ +80°C	-30°C ~ +80°C
Storage temperature	-40°C ~ +85°C	-40°C ~ +85°C	-40°C ~ +85°C	-40°C ~ +85°C
Product approval			CE, FCC	CE, FCC

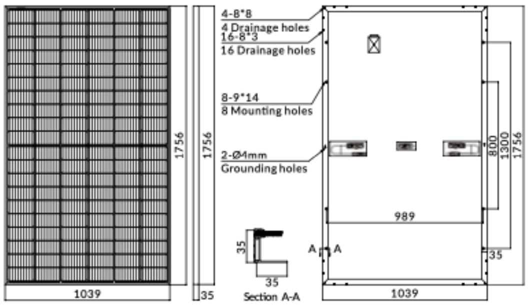
Figure 45: Display datasheet

b. Solar panel

LUXPOWER® Mono I 360 - 380W **Quality Maker**

MECHANICAL CHARACTERISTICS

Solar Cells	Mono
No. of Cells	120 (6x20)
Dimensions	1756 x 1039 x 35mm
Weight	20.0kgs
Front Glass	3.2mm coated tempered glass
Frame	Anodized aluminium alloy
Junction Box	Ip68 rated (3 by pass diodes)
Output Cables	$4.0mm^2$
	300mm (+) / 300mm (-)
	Length can be customized
Connectors	Mc4 compatible
Mechanical load test	5400Pa



ELECTRICAL PARAMETERS

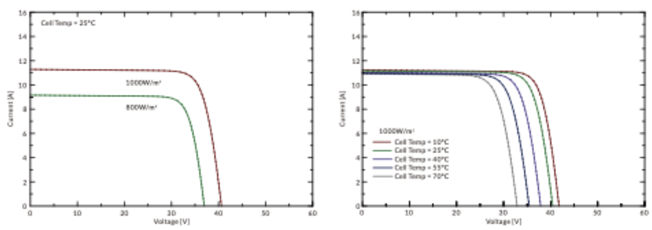
POWER CLASS	LNSK-360M		LNSK-365M		LNSK-370M		LNSK-375M		LNSK-380M	
	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT
Maximum power (Pmax)	360W	265W	365W	268W	370W	271W	375W	274W	380W	277W
Open Circuit Voltage (Voc)	40.79V	37.45V	40.99V	37.55V	41.18V	37.66V	41.37V	37.76V	41.57V	37.86V
Short Circuit Current (Isc)	11.18A	9.01A	11.26A	9.07A	11.34A	9.13A	11.42A	9.19A	11.50A	9.25A
Voltage at Maximum power (Vmpp)	33.71V	30.96V	33.92V	31.09V	34.13V	31.22V	34.34V	31.35V	34.55V	31.48V
Current Maximum Power (Impp)	10.68A	8.56A	10.76A	8.62A	10.84A	8.68A	10.92A	8.74A	11.00A	8.80A
MODULE EFFICIENCY (%)	19.73%		20.01%		20.28%		20.55%		20.83%	

STC: Irradiance $1000W/m^2$, cell temperature 25°C, AM1.5G **NOCT:** Irradiance $800W/m^2$, ambient temperature 20°C, wind speed 1m/s, AM1.5G

PACKING CONFIGURATION

Container	20'GP	40'HQ
Pieces per pallet	31	31
Pallets per container	6	26
Pieces per container	186	806

I-V CURVE LNSK-375M/I-V



OPERATING CHARACTERISTICS

Operating Module Temperature	-40°C to + 85°C
Maximun System Voltage	1500 DC (IEC)
Maximun Series Fuse Rating	20A
Power Tolerance	0/+5W

TEMPERATURE CHARACTERISTICS

Nominal Operating Temperature (Noct)	45±2°C
Temperature Coefficient of Pmax	-0.36%°C
Temperature Coefficient of Voc	-0.28%°C
Temperature Coefficient of Isc	+0.05%°C

Note: Due to continuous technical innovation, R&D and improvement ,technical data above mentioned may be of modification accordingly. LUXEN SOLAR have the sole right to make such modification at anytime without further notice.

c. Battery

	ULTRA 175 48V_280Ah	ULTRA 175 48V_560Ah	ULTRA 175 *Configuration* 3 x 48V_280Ah	ULTRA 175 *Configuration* 2 x 48V_560Ah
Product code With base frame	109639	109640		
Product code Without base frame	109624	-		
Mechanical characteristics				
Equipment dimensions (mm)				
Width	765			
Depth	405			
Height	600			
Height w/o base frame	470	-		
Equipment total weight (kg)	105	210		
Finish / Battery cover	IP30			
Electrical characteristics				
Rated voltage (V)	48		48	
Maximum voltage	52,2		52,2	
Minimum voltage	43		43	
Rated capacity (Ah)	**280**	**560**	**840**	**1120**
Rated energy (kWh)	13,5	27	40,5	54
Cyclability	> 5000 (80%DOD)			
Type of communications	CAN Bus			
Electrical safeguards				
Overload	ok			
Over-discharge	ok			
Short-circuit	ok			
Over-current	ok			
Over-temperature	ok			
Passive balancing	ok			
Current level (A)				
Maximum continuous charge current	175	320	450	500
Recommended continuous charge current	140	280	400	475
Rated continuous discharge current	140	280	400	475
Maximum continuous discharge current	175; (8kW)	340; (15kW)	500 (22,5kW)	575 (26kW)
Peak discharge (1) current/time	225 (5 min); (10kW)	450 (5 min); (20kW)	600 (5 min); (26kW)	800 (5 min); (35kW)
Peak discharge (2) current/time	270 (5s); (12kW)	540 (5s); (24kW)	750 (5s); (32kW)	875 (5s); (40kW)
Peak discharge (3) current/time	400 (<1s)	800 (<1s)	1000 (<1s)	1000 (<1s)
Electrical connections				
Power	REMA SR 350 Connector Grey (Similar connector is supplied for installation with pins for 95mm²) For installations with more than 2 Ultra modules, the use of a Busbar is recommended (not included)			
Communications				
Connector	RJ45			
Type approval				
	CE Mark			
	UN 38.3			
Accessories				
109637	TCC CAN for communications with Victron, Sunny Island and Studer inverters			
109642	Inverters RJ45 extension cable to connect more than 2 Ultra modules to communications			

d. MPPT

victron energy
BLUE POWER

BlueSolar Charge Controllers MPPT 150/70 & 150/85

www.victronenergy.com

Solar Charge Controllers MPPT 150/70 and 150/85

PV voltage up to 150 V

The BlueSolar MPPT 150/70 and 150/85 charge controllers will charge a lower nominal-voltage battery from a higher nominal voltage PV array.
The controller will automatically adjust to a 12, 24, 36, or 48V nominal battery voltage.

Ultra-fast Maximum Power Point Tracking (MPPT)

Especially in case of a clouded sky, when light intensity is changing continuously, an ultra-fast MPPT controller will improve energy harvest by up to 30% compared to PWM charge controllers and by up to 10% compared to slower MPPT controllers.

Advanced Maximum Power Point Detection in case of partial shading conditions

If partial shading occurs, two or more maximum power points may be present on the power-voltage curve.
Conventional MPPT's tend to lock to a local MPP, which may not be the optimum MPP.
The innovative BlueSolar algorithm will always maximize energy harvest by locking to the optimum MPP.

Outstanding conversion efficiency

Maximum efficiency exceeds 98%. Full output current up to 40°C (104°F).

Flexible charge algorithm

Several preconfigured algorithms. One user programmable algorithm.
Manual or automatic equalisation.
Battery temperature sensor. Battery voltage sense option.

Programmable auxiliary relay

For alarm or generator start purposes

Extensive electronic protection

Over-temperature protection and power derating when temperature is high.
PV short circuit and PV reverse polarity protection.
Reverse current protection.

CAN bus

To parallel up to 25 units, to connect to a ColorControl panel or to connect to a CAN bus network

BlueSolar Charge Controller	MPPT 150/70	MPPT 150/85
Nominal battery voltage	12 / 24 / 36 / 48V Auto Select	
Rated charge current	70A @ 40°C (104°F)	85A @ 40°C (104°F)
Maximum solar array input power 1)	12V: 1000W / 24V: 2000W / 36V: 3000W / 48V: 4000W	12V: 1200W / 24V: 2400W / 36V: 3600W / 48V: 4850W
Maximum PV open circuit voltage	150V absolute maximum coldest conditions 145V start-up and operating maximum	
Minimum PV voltage	Battery voltage plus 7 Volt to start Battery voltage plus 2 Volt operating	
Standby power consumption	12V: 0,55W / 24V: 0,75W / 36V: 0,90W / 48V: 1,00W	
Efficiency at full load	12V: 95% / 24V: 96,5% / 36V: 97% / 48V: 97,5%	
Absorption charge	14.4 / 28.8 / 43.2 / 57.6V	
Float charge	13.7 / 27.4 / 41.1 / 54.8V	
Equalization charge	15.0 / 30.0 / 45 / 60V	
Remote battery temperature sensor	Yes	
Default temperature compensation setting	-2,7 mV/°C per 2V battery cell	
Remote on/off	Yes	
Programmable relay	DPST AC rating: 240VAC / 4A DC rating: 4A up to 35VDC, 1A up to 60VDC	
Communication port	VE.Can: two paralleled RJ45 connectors, NMEA2000 protocol	
Parallel operation	Yes, through VE.Can. Max 25 units in parallel	
Operating temperature	-40°C to 60°C with output current derating above 40°C	
Cooling	Low noise fan assisted	
Humidity (non condensing)	Max. 95%	
Terminal size	35mm² / AWG2	
Material & color	Aluminium, blue RAL 5012	
Protection class	IP20	
Weight	4,2kg	
Dimensions (h x w x d)	350 x 160 x 135mm	
Mounting	Vertical wall mount Indoor only	
Safety	EN/IEC 62109-1	
EMC	EN 61000-6-1, EN 61000-6-3	
1) If more solar power is connected, the controller will limit input power to the stated maximum		

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victron energy
BLUE POWER

e. Step-down DC-DC converter

DITEK® Surge Protection

DTK-2MHLPF Series

Modular Low Voltage Surge Protectors

DITEK's DTK-2MHLPF Series of low voltage surge protectors provide robust protection in a compact package. This series was designed to remove load instead of shorting to ground. Convenient field-replaceable modules offer ease of installation, and the Snap-Track base system allows installers to protect multiple circuits while utilizing a common ground point.

DTK-2MHLP24F DTK-2MHLP24FWB

Product Features

- Protects (2) low voltage circuit pairs per module
- Hybrid design utilizing SAD and GDT technologies
- Opens circuit when compromised
- Field-replaceable modular design with single point ground for fast and easy installation
- Six voltage configurations available to protect various types of circuits
- Hardwired multi-base mounting system allows protection for up to (10) pairs with a common ground
- Suitable for use on both AC and DC low voltage circuits

Applications

- Fire Alarm Panel SLC, PIV and IDC Circuits
- Burglar Alarm Panel IDC Circuits
- 4-20mA Current Loops

Accessories

- To order module with base, add "WB" to end of part number
- Test Module Kit, p/n DTK-2MHLPTM

Technical Specifications

DTK-2MHLP	5F	12F	24F	36F	48F	75F
Service Voltage:	5V	12V	24V	36V	48V	75V
MCOV:	6V	18V	33V	48V	64V	90V
Clamping Voltage:	6.8V	21.6V	39V	57V	76V	108V
Protection Modes:	Common Mode (L-G)					
Surge Current Rating:	20,000A					
Max. Continuous Current:	1A					
Failure Mode:	Open Circuit					

Mechanical Specifications

Base Connection Method:	Hardwired terminals, 30-12 AWG	
Module Connection Method:	Edge card into mounting base	
Housing:	ABS	
Operating Temperature:	-40°F - 158°F (-40°C - 70°C)	
Maximum Humidity:	95% non-condensing	
Dimensions:	**Module** 2.1" L x 1.4" W x 1.9" H (53 mm x 36 mm x 48 mm)	**Module with Base** 3.25" L x 1.5" W x 2.6" H (83 mm x 38 mm x 66 mm)
Weight:	1.2 oz (34 g)	2.8 oz (79 g)

Quality Standards & Approvals

Certifications:	UL497B
Warranty:	10 Year Limited Warranty

ISO 9001 NFPA UL LISTED MADE IN U. S. A.

DITEK Surge Protection, Largo, FL 33771 ♦ Sales: 800-753-2345 ♦ www.diteksurgeprotection.com ♦ SPS-100010-003 Rev 3 12/20

f. Mounting rail datasheet

Tech Brief

XR Rail Family

The XR Rail Family offers the strength of a curved rail in three targeted sizes. Each size supports specific design loads, while minimizing material costs. Depending on your location, there is an XR Rail to match.

XR10

XR10 is a sleek, low-profile mounting rail, designed for regions with light or no snow. It achieves spans up to 6 feet, while remaining light and economical.

- 6' spanning capability
- Moderate load capability
- Clear & black anodized finish
- Internal splices available

XR100

XR100 is the ultimate residential mounting rail. It supports a range of wind and snow conditions, while also maximizing spans up to 10 feet.

- 10' spanning capability
- Heavy load capability
- Clear & black anodized finish
- Internal splices available

XR1000

XR1000 is a heavyweight among solar mounting rails. It's built to handle extreme climates and spans up to 12 feet for commercial applications.

- 12' spanning capability
- Extreme load capability
- Clear anodized finish
- Internal splices available

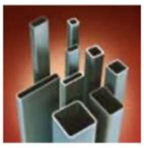
Rail Selection

The table below was prepared in compliance with applicable engineering codes and standards.* Values are based on the following criteria: ASCE 7-16, Gable Roof Flush Mount, Roof Zones 1 & 2e, Exposure B, Roof Slope of 8 to 20 degrees and Mean Building Height of 30 ft. Visit IronRidge.com for detailed certification letters.

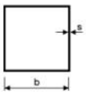
Load		Rail Span					
Snow (PSF)	Wind (MPH)	4'	5' 4"	6'	8'	10'	12'
None	90						
	120						
	140	XR10		XR100		XR1000	
	160						
20	90						
	120						
	140						
	160						
30	90						
	160						
40	90						
	160						
80	160						
120	160						

*Table is meant to be a simplified span chart for conveying general rail capabilities. Use approved certification letters for actual design guidance.

g. Beam datasheet



DIMENSIONAL TABLE



Size b mm	W.T. s mm	Linear mass Kg/m	Cross-sectional area A cm^2	Second moment of area I cm^4	Radius of gyration i cm	Elastic section modulus W cm^3	Torsional inertia constant J cm^4	Torsional mudulus constant C cm^3
80	3,6	8,53	10,90	105,00	3,11	26,20	164,00	38,50
	4,0	9,41	12,00	114,00	3,09	28,60	180,00	41,90
	5,0	11,60	14,70	137,00	3,05	34,20	217,00	49,80
	6,3	14,20	18,10	162,00	2,99	40,50	262,00	58,70
	7,1	15,80	20,20	176,00	2,95	43,90	286,00	63,50
	8,0	17,50	22,40	189,00	2,91	47,30	312,00	68,30
	10,0	21,10	26,90	214,00	2,82	53,50	360,00	76,80
	11,0	22,80	29,10	223,00	2,77	55,80	380,00	80,10
	12,5	25,20	32,10	234,00	2,70	58,60	404,00	83,80
90	3,6	9,66	12,30	152,00	3,52	33,80	237,00	49,70
	4,0	10,70	13,60	166,00	3,50	37,00	260,00	54,20
	5,0	13,10	16,70	200,00	3,45	44,40	316,00	64,80
	6,3	16,20	20,70	238,00	3,40	53,00	382,00	77,00
	7,1	18,10	23,00	260,00	3,36	57,70	419,00	83,70
	8,0	20,10	25,60	281,00	3,32	62,60	459,00	90,50
	10,0	24,30	30,90	322,00	3,23	71,60	536,00	103,00
	12,5	29,10	37,10	359,00	3,11	79,80	612,00	114,00
100	4,0	11,90	15,20	232,00	3,91	46,40	361,00	68,20
	5,0	14,70	18,70	279,00	3,86	55,90	439,00	81,80
	6,3	18,20	23,20	336,00	3,80	67,10	534,00	97,80
	7,1	20,30	25,80	367,00	3,77	73,40	589,00	107,00
	8,0	22,60	28,80	400,00	3,73	79,90	646,00	116,00
	10,0	27,40	34,90	462,00	3,64	92,40	761,00	133,00
	11,0	29,70	37,90	488,00	3,59	97,70	812,00	141,00
	12,5	33,00	42,10	522,00	3,52	104,00	879,00	150,00
	14,2	36,60	46,60	553,00	3,44	111,00	943,00	158,00
110	4,0	13,20	16,80	313,00	4,32	56,80	485,00	83,70
	5,0	16,30	20,70	378,00	4,27	68,80	592,00	101,00
	6,3	20,20	25,70	456,00	4,21	83,00	722,00	121,00
	7,1	22,50	28,70	500,00	4,18	91,00	798,00	133,00
	8,0	25,10	32,00	547,00	4,14	99,40	878,00	144,00
	10,0	30,60	38,90	637,00	4,05	116,00	1040,00	168,00
	11,0	33,20	42,30	677,00	4,00	123,00	1110,00	178,00
	12,5	37,00	47,10	728,00	3,93	132,00	1210,00	191,00
	14,2	41,00	52,30	776,00	3,85	141,00	1310,00	203,00

sicam 19

h. Ceiling trusses datasheet

Truss Loadings

Imposed loads in accordance with BS 6399.

RAFTER LOADS

Long Term Loads: For standard concrete interlocking tiles the loads are as follows:

Tile weight	575 N/m^2
Truss self weight	75 N/m^2
Battens & felt	35 N/m^2
	685 N/m^2

Where a rafter bay forms part of the room (in raised tie and attic trusses) an additional load of 250 N/m^2 is added for the ceiling finishes.

Medium Term Loads: For small buildings ie. total floor area less than 200m^2 and where roof shape calculations have not been made, the 0 - 30 degrees site snow load is 750 N/m^2. This reduces for pitches greater than 30 degrees, reducing to zero at 60 degrees.

Short Term Loads: A man point load of 675 N (900 N x 75% for load sharing) is applied to rafters up to 30 degrees. However, experience has shown that for standard truss configurations designed for 750 N/m^2 snow loads, the rafter man point load is not a critical load case.

Wind Loads: Wind loads are calculated in accordance with CP3: Chapter V part 2, all structures are assumed to be of Class B.

CEILING TIE LOADS

Long Term Loads: These are as follows:

Truss self weight	75 N/m^2
Plaster board	175 N/m^2
Imposed load (loft storage)	250 N/m^2
Total long term load	500 N/m^2

Tank load at 2 node points normally 450 N per node (see tank details on page 19).

Short Term Loads: A man point load of 675 N (900 N x 75% for load sharing) is applied at a point likely to produce the highest stress in the ceiling tie.

ADDITIONAL LONG TERM LOADS FOR ATTIC TRUSSES

The floor area will be loaded as follows:

Domestic imposed load	1500 N/m^2
Partition loads	250 N/m^2
Truss self weight	75 N/m^2
Plaster board	175 N/m^2
Floor boarding	250 N/m^2
	2250 N/m^2

Point loads are applied to the nodes at the side of the room for the plaster board of 250 N/m^2. x height at the side of the room. A load of 250 N/m^2 is applied to rafters where they form part of the room.

D. Calculations

a. Winter

$day \equiv 24\ hr$ $Wh \equiv 1\ W \cdot 1\ hr$ $kWh \equiv 1000\ Wh$ $Ah \equiv 1\ A \cdot hr$

POWER CONSUMPTION: WORST SCENARIO

Bikes data:
36V integrated Li-ION battery, capacity: 400 WH, 10.4Ah (range: 80 km approx)

$Cb := 400\ Wh$ $n_{bikes} := 10$ $n_{cd} := 2$ $C_{bikes} := Cb \cdot n_{bikes} \cdot n_{cd} = 8\ kWh$

Lighting, signal lights and display data:

Sunrise December: 8:00 am.
Sunset December: 5:00 pm.

$P_l := 20\ W$ $n_l := 2$ $t_l := 15 \cdot hr$

$C_l := P_l \cdot n_l \cdot t_l = 0.6\ kWh$

$P_d := 16 \cdot W$ $t_d := 24\ hr$

$C_d := P_d \cdot t_d = 0.384\ kWh$

$P_{slgreen} := 62.5\ mW$ $n_{sl} := n_{bikes}$ $t_{sl} := 12 \cdot hr$

$P_{slred} := 75\ mW$

$C_{sl} := P_{slgreen} \cdot n_{sl} \cdot t_{sl} + P_{slred} \cdot n_{sl} \cdot t_{sl} = 0.017\ kWh$ $C_{sl} + C_l = 0.617\ kWh$

TOTAL POWER CONSUMPTION $C_{sys} := \dfrac{C_{bikes} + C_l + C_d + C_{sl}}{1\ day} = 9.001\ \dfrac{kWh}{day}$

$V_{sys} := 48\ V$

Load current in parallel: $I_l := \dfrac{C_{sys}}{V_{sys}} = 187.51\ \dfrac{Ah}{day}$ $ESH := 3.66$

$I_p := \dfrac{I_l}{ESH} = 51.232\ \dfrac{Ah}{day}$ $I_m := 10.76\ A$

MINIMUM NUMBER OF SOLAR PANELS

$N_p := \dfrac{I_p}{I_m} = 4.761\ \dfrac{hr}{day}$ **Np must be at least 5**

b. Summer

$day \equiv 24\ hr$ $Wh \equiv 1\ W \cdot 1\ hr$ $kWh \equiv 1000\ Wh$ $Ah \equiv 1\ A \cdot 1\ hr$

POWER CONSUMPTION: BEST SCENARIO

Bikes data:
36V integrated Li-ION battery, capacity: 400 WH, 10.4Ah (range: 80 km approx)

$Cb := 400\ Wh$ $n_{bikes} := 10$ $n_{cd} := 2$ $C_{bikes} := Cb \cdot n_{bikes} \cdot n_{cd} = 8\ kWh$

Lighting, signal lights and display data:

Sunrise December: 06:20 am.
Sunset December: 21:20 pm.

$P_l := 20\ W$ $n_l := 2$ $t_l := 9 \cdot hr$

$C_l := P_l \cdot n_l \cdot t_l = 0.36\ kWh$

$P_d := 16 \cdot W$ $t_d := 24\ hr$ $C_d := P_d \cdot t_d = 0.384\ kWh$

$P_{slgreen} := 62.5\ mW$ $n_{sl} := n_{bikes}$ $t_{sl} := 12 \cdot hr$

$P_{slred} := 75\ mW$

$C_{sl} := P_{slgreen} \cdot n_{sl} \cdot t_{sl} + P_{slred} \cdot n_{sl} \cdot t_{sl} = 0.017\ kWh$

TOTAL POWER CONSUMPTION $C_{sys} := \frac{C_{bikes} + C_l + C_d + C_{sl}}{1\ day} = 8.761\ \frac{kWh}{day}$

$V_{sys} := 48\ V$

Load current in parallel: $I_l := \frac{C_{sys}}{V_{sys}} = 182.51\ \frac{Ah}{day}$ $ESH := 6.96$

$I_p := \frac{I_l}{ESH} = 26.223\ \frac{Ah}{day}$ $I_m := 10.76\ A$

MINIMUM NUMBER OF SOLAR PANELS

$N_p := \frac{I_p}{I_m} = 2.437\ \frac{hr}{day}$ **Np must be at least 3**

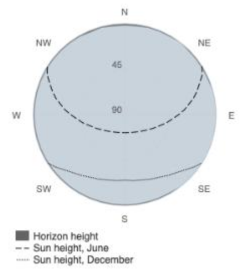
c. Equivalent Solar Hours

PVGIS-5 geo-temporal irradiation database

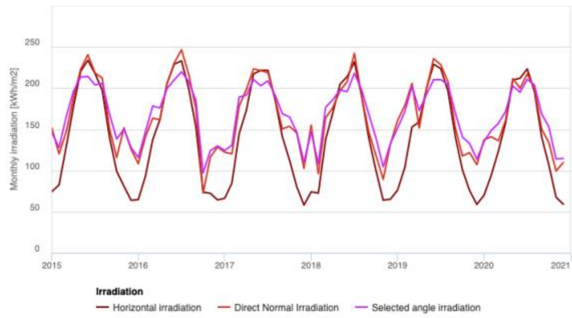
Provided inputs

Latitude/Longitude:	41.325,2.103
Horizon:	Calculated
Database used	PVGIS-SARAH2
Start year:	2015
End year:	2020
Variables included in this report:	
Global horizontal irradiation:	Yes
Direct Normal Irradiation:	Yes
Global irradiation optimum angle:	No
Global irradiation at angle 38°	Yes
Diffuse/global ratio	Yes
Average temperature	Yes

Outline of horizon at chosen location:



Monthly solar irradiation estimates



Global horizontal irradiation

Month	2015	2016	2017	2018	2019	2020
January	74.49	64.69	66.34	74.13	76.3	70.02
February	82.62	93.42	84.91	72.66	103.6	94.24
March	129.1	137.18	144.55	137.31	152.72	123.73
April	177.4	161.82	172.87	169.83	158.9	157.88
May	220.26	205.74	217.09	204.5	198.96	209.7
June	233.57	228.99	221.49	213.83	228.79	211.86
July	217.51	232.88	221.38	231.7	223.47	223.14
August	197	199.27	185.36	190.53	196.18	195.89
September	140.51	152.53	140.99	139.43	141.72	140.79
October	99.1	73.77	112.44	100	100.95	106.81
November	81.13	72.35	80.36	64.07	75.69	67.63
December	63.97	64.39	58.14	65.24	59.01	59.25

Direct Normal Irradiation

Month	2015	2016	2017	2018	2019	2020
January	151.59	108.27	122.21	154.89	160.85	137.35
February	120.17	141.05	120.17	96.18	178.62	140.91
March	147.2	163.34	177.96	163.65	205.58	136.05
April	188.32	161.69	198.28	176.21	151.48	161.35
May	222.77	205.68	223.21	196.74	198.37	211.54
June	240.35	230.66	221.08	207.54	235.62	199.66
July	218.16	246.31	218.72	242.09	228.16	217.12
August	212.14	216.66	187.02	190.8	207.6	199.55
September	150.87	174.98	150.5	146.99	152.53	150.13
October	115.7	72.85	153.58	118.42	117.68	133.98
November	151.71	116.16	145.64	89.34	121.68	99.38
December	125.72	128.57	102.58	131.75	107.09	109.58

Global irradiation at angle

Month	2015	2016	2017	2018	2019
January	145.84	115.68	124.34	146.41	151.41
February	127.96	147.4	130.6	108.28	171.32
March	165.39	178.09	189.13	176.44	202.09
April	195.91	175.87	191.26	185.7	172.75
May	213.3	199.49	210.27	197.74	192.06
June	214.01	210.02	202.82	195.59	210.17
July	203.78	219.55	208.71	217.89	210.11
August	205.63	207.95	191.3	197.95	204.01
September	168.78	184.82	168.88	168.31	170.11
October	138.2	97.2	164.9	139.5	140.71
November	150.14	124	146.42	104.49	132.66
December	128.04	129.79	110.52	132.46	113.66

Joint Research Centre

Report generated on 2022/05/09

d. Maximum Voltage:

$$Temperature\ coefficient\ of\ P_{max} = -0{,}36\,\%/°C = -0{,}0036/°C$$

$$Temperature\ coefficient\ of\ V_{OC} = Temp.Coef.P_{max} \cdot Open\ Circuit\ Voltage\ V_{OC}$$
$$= -0{,}0036/°C \cdot 40{,}99V = -0{,}1475\,V_{OC}/°C$$

$$-3°C - 25°C = -28°C$$

$$-28°C \cdot 0{,}147\,V_{OC}/°C = 4{,}13V$$

$$Maximum\ voltage = Open\ Circuit\ Voltage + 4{,}13V = 40{,}99V + 4{,}13V = 45{,}12V$$

e. Minimum Voltage:

$$Temperature\ coefficient\ of\ P_{max} = -0{,}36\,\%/°C = -0{,}0036/°C$$

$$Temperature\ coefficient\ of\ V_{mpp}$$
$$= Temp.Coef.P_{max} \cdot Voltage\ at\ Maximum\ Power\ V_{mpp}$$
$$= -0{,}0036/°C \cdot 33{,}92\ V = -0{,}122\,V/°C$$

$$64°C - 25°C = 39°C$$

$$39°C \cdot 0{,}122\,V_{mpp}/°C = 4{,}76V$$

$$Minimum\ Voltage = Voltage\ at\ Maximum\ Power - 4{,}76V = 33{,}92V - 4{,}76V$$
$$= 29{,}16V$$

f. Battery sizing

Battery sizing

$$B_c := \frac{C_{sys} \cdot 2\ day}{V_{sys} \cdot 0.7 \cdot 0.85} = 630.287\ Ah \qquad LC := 5000 \qquad C_{sys} = 375.021\ W$$

$$B_{rc} := 840\ Ah$$

$$At := \frac{V_{sys} \cdot 0.7 \cdot 0.85 \cdot B_{rc}}{C_{sys}} = 63.971\ hr$$

$$E := B_{rc} \cdot V_{sys} = 40.32\ kWh$$

$$Cbattery := 15\% \ \frac{E}{1\ day} = 6.048\ \frac{1}{day} \cdot kWh$$

$$C_{sys2} := Cbattery + C_{sys} = 15.049\ \frac{kWh}{day}$$

Load current in parallel: $I_l := \frac{C_{sys2}}{V_{sys}} = 313.51\ \frac{Ah}{day}$ $\qquad ESH := 3.66$

$$I_p := \frac{I_l}{ESH} = 85.659\ \frac{Ah}{day} \qquad I_m := 10.76\ A$$

MINIMUM NUMBER OF SOLAR PANELS

$$N_p := \frac{I_p}{I_m} = 7.961\ \frac{hr}{day}$$

Np must be at least 8

g. Total losses

- The temperature of the PV module:

$$Avarage\ temperature\ in\ Barcelona = 16{,}1°C$$

$$Temperature\ of\ the\ cells = 16{,}1°C + 25°C = 41{,}1°C$$

$$Difference\ etween\ cell\ temperature\ and\ STC = 41{,}1°C - 25°C = 16{,}1°C$$

$$Temperature\ coefficient\ of\ P_{max} = -0{,}36\,\%/°C = -0{,}0036/°C$$

$$-0{,}0036/°C \cdot 16{,}1°C = -0{,}05796$$

$$f_{temp} = 1 - 0{,}05796 = 0{,}942 = 94{,}2\%$$

- Dirt and Soiling:

$$f_{dirt} = 0{,}90 = 90\%\ (Standard\ Value)$$

- Manufacturer's tolerance:

$$f_{man} = 1 = 100\%\ (Not\ Specified)$$

- Shading:

$$f_{shading} = 1 = 100\%\ (Correct\ Place\ of\ Installation)$$

- Orientation and Module tilt angle:

$$f_{orientation} = 1 = 100\%\ (Document)$$

- Voltage Drop:

$$f_{Vdrop} = 0{,}95 = 95\%\ (Standard\ Value)$$

- MPPT Efficiency:

$$f_{MPPT} = 0{,}975\ (datasheet)$$

h. PV's array rated power

$$\boldsymbol{PV's\ array\ rated\ power = 8\ solar\ panels \cdot 365W = 2,92\ kW}$$

i. System yield

$$\boldsymbol{Total\ yield\ of\ the\ system = 2,92\ kW \cdot 0,785 \cdot 1938,15\ \frac{kWh/m^2}{year} = 4301,54\frac{kWh}{year}}$$

j. The bike’s charging station´s annual consumption

$$EBike\ Charging\ Station\ \text{consumption} = 9\,\frac{kWh}{day} \cdot 365\ days = 3285\ kWh$$

k. The surface area of the solar panel roof

$$Area\ of\ solar\ panels\ roof = 3{,}8\ m \cdot 10{,}4\ m = 39{,}59\ m^2$$

l. Length of the structure

$$8 \cdot 103{,}9\ cm = 831{,}2\ cm$$

m. Width of the roof

$$\frac{3\ m}{\cos 38°} = 3{,}8\ m$$

n. Area of solar panels floor

$$Area\ of\ solar\ panels\ floor = 3\ m\ \cdot 10{,}4\ m = 31{,}2\ m^2$$

o. Height of the rear beam

$$Height\ of\ the\ rear\ beam = (\sin 38° \cdot 3{,}8\ m) + 2\ m = 4{,}344\ m \approx 4{,}4\ m$$

p. Dead load

$$Weight\ 8\ load\ of\ solar\ panel = 8 \cdot\ 20\ Kg \cdot\ 9{,}81\ \ m/s^2 = 1569{,}6\ N$$

$$Weight\ of\ mounting\ rail\ =\ 2.7\ Kg\ \cdot\ 2\ \cdot\ 9.81\ \ m/s^2 = 52{,}974\ N$$

$$Weight\ of\ truss\ load\ (mono - pitch\ roof) = 75\ N/m^2 \cdot base\ floor\ area\ (40\ m^2) = 3\ KN$$

$$Weight\ of\ screw, clamps\ =\ Insignificant$$

$$Weight\ for\ water\ resistant\ laminate, rolled\ roofing, and\ fire\ proofed\ covering = Insignificant$$

$$Weight\ of\ plaster\ board\ =\ 175\frac{N}{m^2}\cdot\ 40\ m^2\ =\ 7KN$$

$$Snow\ wind\ +\ Wind\ load\ =\ 1.0084\ KN/m^2\ \cdot\ 40\ m^2\ =\ 10KN$$

$$2\ person\ loas = 100\ Kg\cdot 2\cdot 9{,}81\ m/s^2 = 2KN$$

$$Total\ ded\ load: 1569.6\ N + 52.974\ N + 3\ KN + 7\ KN + 10\ KN + 2\ KN = 24\ KN$$

$$Load\ distributed\ by\ 4\ beams\ = \frac{24KN}{4}\ =\ 6KN$$

q. Basic wind velocity

$$V_b = 1.0\cdot 1.0\cdot 29 = 29\ m/s$$

r. Snow load coefficient

$$\alpha = 38°$$

$$30° < \alpha < 60°$$

$$\mu_1 = \frac{0{,}8\cdot(60-\alpha)}{30} = 0{,}5867\ KN/m^2$$

s. Characteristic value of snow on the ground

$$s_k = (0{,}190Z - 0{,}095)\left[1 + \left(\frac{A}{524}\right)^2\right] = 0{,}6653\ KN/m^2$$

t. Snow load

$$S = 0{,}5687\cdot 1\cdot 1\cdot 0{,}6653 = 0{,}3904\ KN/m^2$$

u. Horizontal force

$0.673 kN/m^2 \times 1m = 0.673\ kN/m$

v. Calculation of the distribution of normal tension

$\sigma = -\frac{6kN}{25.60cm^2} - \frac{688.5kNcm}{281cm^4}(4.5\ cm) = 11026.04\ N\ cm^{-2} = 1102.6\ kg\ cm^{-2}$

w. Calculation of thick or thin profile

e = 8.0 mm

0.1 x (90-8-8) = 7.4 mm

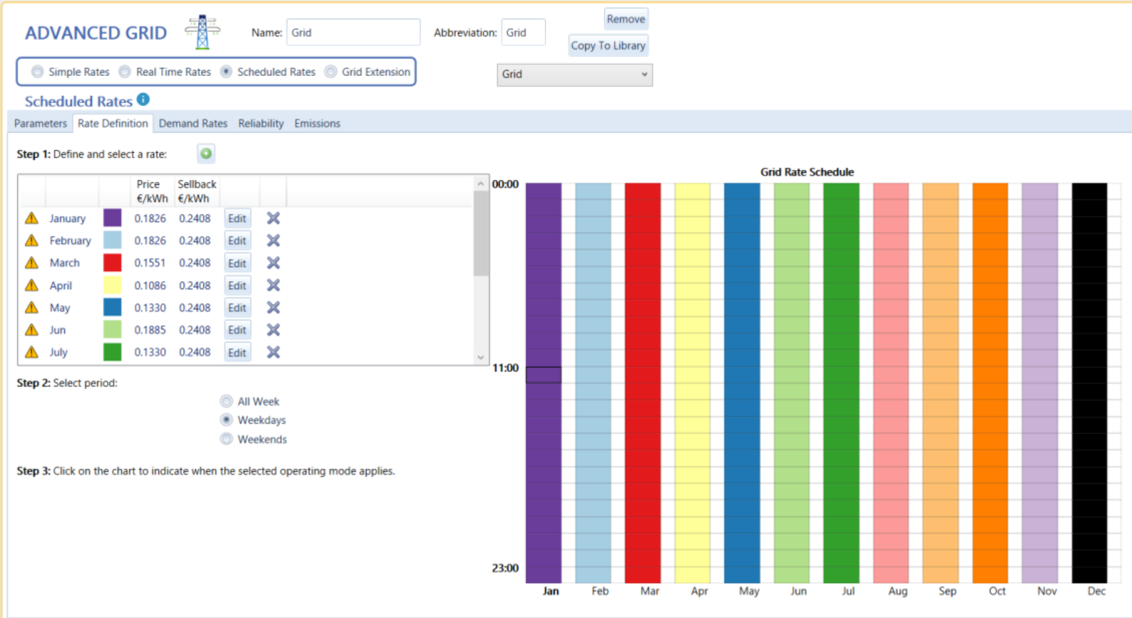
e > 7.4 mm

x. Calculation of Von Mises equivalent stress

$\tau = 0$

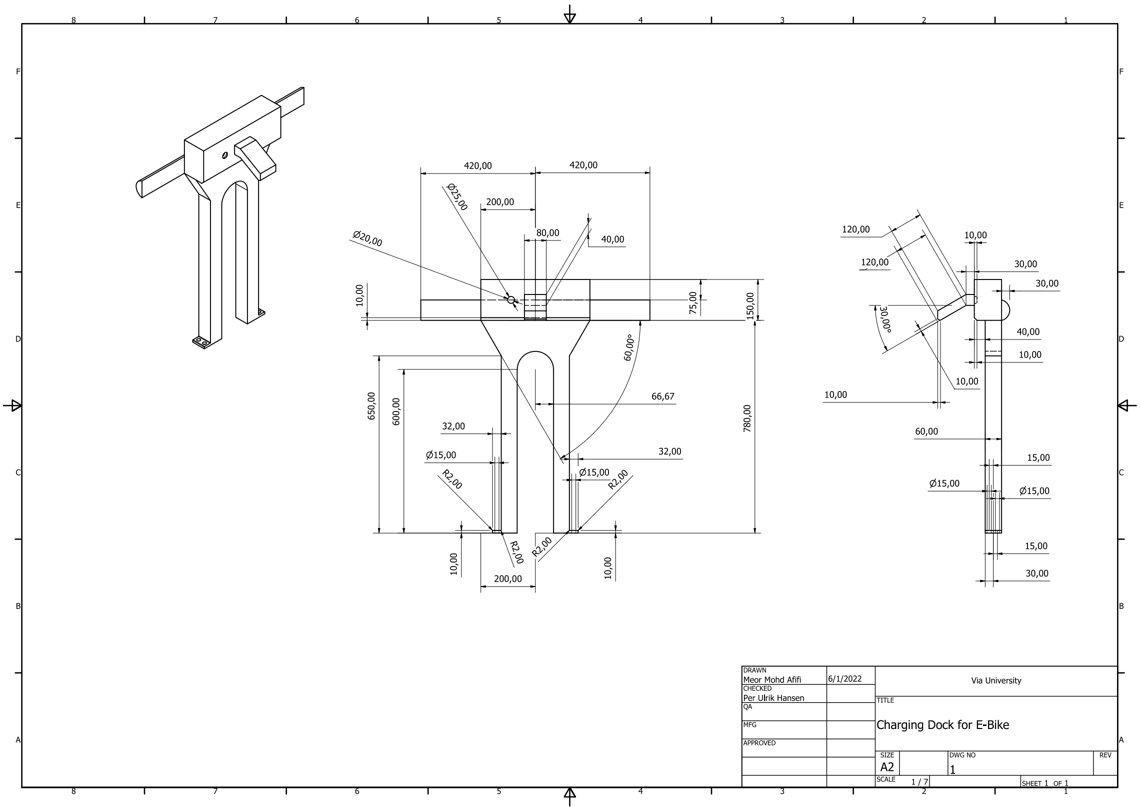
$\sigma_{eq\ von\ mises} = \sqrt{\sigma^2} = \sigma$

E. Grid Pricing



		JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	WEEKEND AND HOLIDAYS
0	1	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102
1	2	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102
2	3	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102
3	4	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102
4	5	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102
5	6	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102
6	7	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102
7	8	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102
8	9	0.203	0.203	0.151	0.097	0.097	0.127	0.203	0.127	0.127	0.097	0.151	0.203	0.102
9	10	0.233	0.233	0.203	0.127	0.127	0.151	0.233	0.151	0.151	0.127	0.203	0.233	0.102
10	11	0.233	0.233	0.203	0.127	0.127	0.151	0.233	0.151	0.151	0.127	0.203	0.233	0.102
11	12	0.233	0.233	0.203	0.127	0.127	0.151	0.233	0.151	0.151	0.127	0.203	0.233	0.102
12	13	0.233	0.233	0.203	0.127	0.127	0.151	0.233	0.151	0.151	0.127	0.203	0.233	0.102
13	14	0.233	0.233	0.203	0.127	0.127	0.151	0.233	0.151	0.151	0.127	0.203	0.233	0.102
14	15	0.203	0.203	0.151	0.097	0.097	0.127	0.203	0.127	0.127	0.097	0.151	0.203	0.102
15	16	0.203	0.203	0.151	0.097	0.097	0.127	0.203	0.127	0.127	0.097	0.151	0.203	0.102
16	17	0.203	0.203	0.151	0.097	0.097	0.127	0.203	0.127	0.127	0.097	0.151	0.203	0.102
17	18	0.203	0.203	0.151	0.097	0.097	0.127	0.203	0.127	0.127	0.097	0.151	0.203	0.102
18	19	0.233	0.233	0.203	0.127	0.127	0.151	0.233	0.151	0.151	0.127	0.203	0.233	0.102
19	20	0.233	0.233	0.203	0.127	0.127	0.151	0.233	0.151	0.151	0.127	0.203	0.233	0.102
20	21	0.233	0.233	0.203	0.127	0.127	0.151	0.233	0.151	0.151	0.127	0.203	0.233	0.102
21	22	0.233	0.233	0.203	0.127	0.127	0.151	0.233	0.151	0.151	0.127	0.203	0.233	0.102
22	23	0.203	0.203	0.151	0.097	0.097	0.127	0.203	0.127	0.127	0.097	0.151	0.203	0.102
23	24	0.203	0.203	0.151	0.097	0.097	0.127	0.203	0.127	0.127	0.097	0.151	0.203	0.102
Average		0.182655	0.182655	0.155137	0.108573	0.108573	0.132909	0.188473	0.132909	0.130307	0.108573	0.155137	0.182655	0.102
Annual		0.130033		0.137161										

Inventor Drawing Sketch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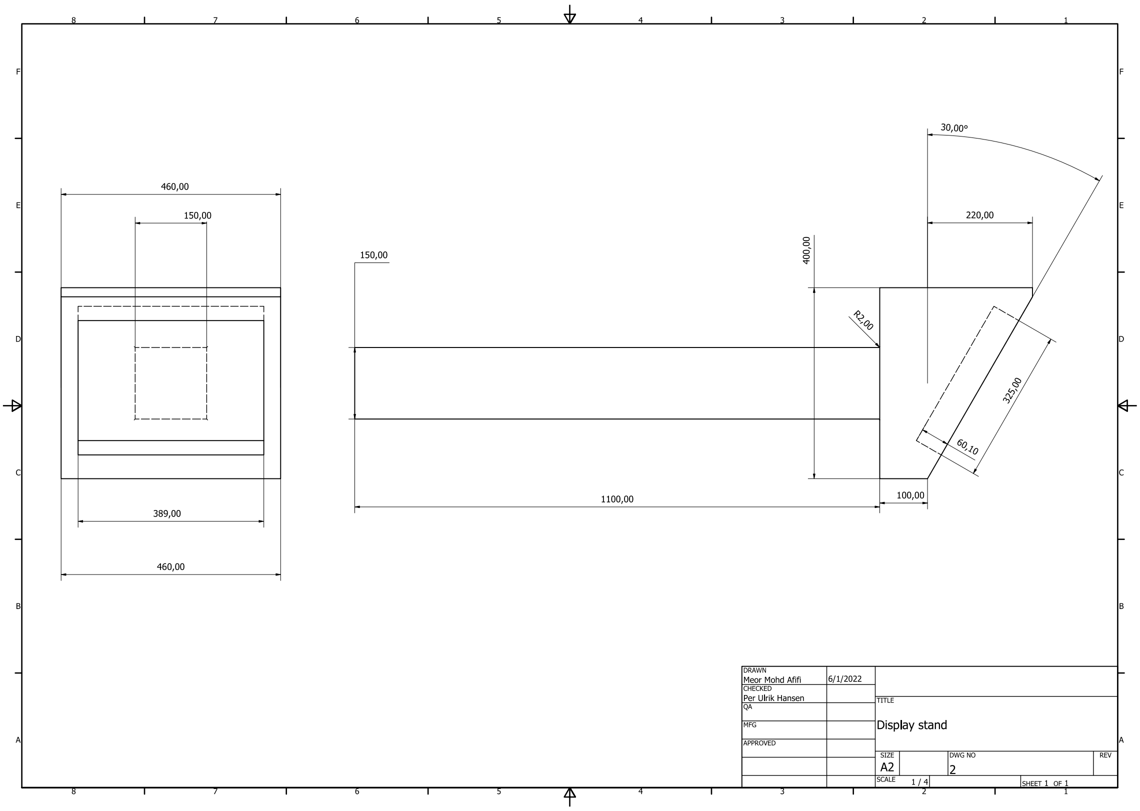
DRAWN
Meor Mohd Afifi
6/1/2022
Via University
CHECKED
Per Ulrik Hansen
TITLE
QA
MFG
Charging Dock for E-Bike
APPROVED
SIZE
A2
DWG NO
1
REV
SCALE
1 / 7
SHEET 1 OF 1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150,00
1100,00
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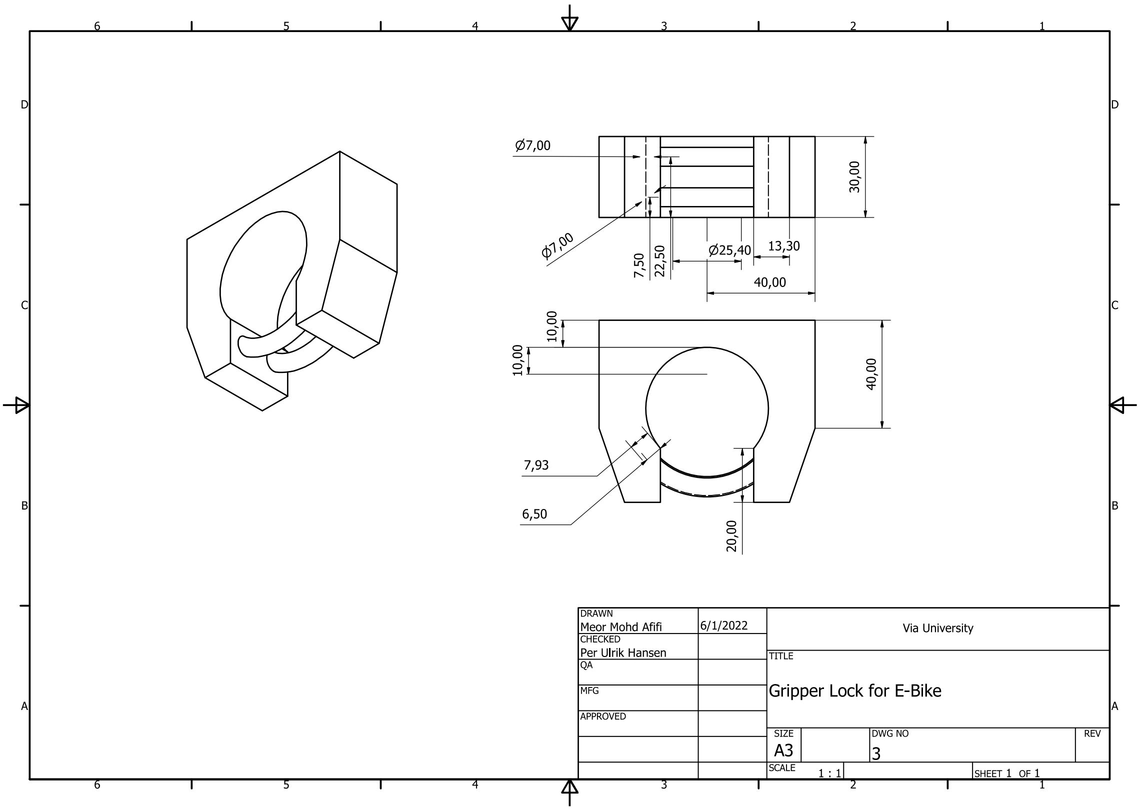
R2,00
30,00°
220,00
325,00
60,10
100,00
DRAWN
Meor Mohd Afifi
6/1/2022
CHECKED
Per Ulrik Hansen
TITLE
QA
MFG
Display stand
APPROVED
SIZE
A2
DWG NO
2
REV
SCALE
1 / 4
SHEET 1 OF 1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22,50
Ø25,40
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30,00
10,00
10,00
40,00
7,93
6,50
20,00
DRAWN
Meor Mohd Afifi
6/1/2022
CHECKED
Per Ulrik Hansen
QA
MFG
APPROVED
Via University
TITLE
Gripper Lock for E-Bike
SIZE
A3
DWG NO
3
REV
SCALE
1 : 1
SHEET 1 OF 1